

RESEARCH MEMORANDUM

INVESTIGATION AT HIGH AND LOW SUBSONIC MACH NUMBERS
OF TWO SYMMETRICAL 6-PERCENT-THICK AIRFOIL SECTIONS

DESIGNED TO HAVE HIGH MAXIMUM LIFT

COEFFICIENTS AT LOW SPEEDS

By Nicholas J. Paradiso

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

An investigation has been made at both high and low subsonic Mach numbers of two symmetrical 6-percent-thick airfoil sections derived to have high maximum lift at low speeds. The low-speed portion (Mach numbers below 0.20) of the investigation included lift, drag, and pitching-moment measurements at Reynolds numbers of 3×10^6 , 6×10^6 , and 9×10^6 for the models in the smooth surface condition. Data were also taken for the models using two locations of roughness. The high-speed portion of the investigation included lift, drag, and pitching-moment measurements for a Mach number range of from about 0.30 to slightly below the tunnel choking Mach number. Comparisons with the NACA 64-006 section characteristics are included.

For Mach numbers below 0.20 both new airfoil sections had maximum section lift coefficients higher than the NACA 64-006, one being 1.220 and the other being 1.040 as compared to 0.82 for the NACA 64-006. Application of the leading-edge type of roughness caused reductions in the value of maximum lift for the new airfoils to approximately the same value as for other 6-percent-thick airfoil sections, whereas application of roughness beginning at 0.05 chord resulted in the same maximum lift as for the airfoil in the smooth condition. The drag characteristics at high subsonic speeds of the two sections showed a marked improvement over those of previously investigated blunt-nose airfoils of the same family. For Mach numbers from 0.30 to 0.65, the drag polars of the two new sections had as good or better characteristics as those of the NACA 64-006 section. At the higher Mach numbers, the NACA 64-006 section had somewhat lower drags than the two new sections for lift coefficients above a certain value which decreased as the Mach number increased.

INTRODUCTION

The derivation of a series of thin symmetrical airfoils designed to have high maximum lift coefficients at low speeds and experimental results for two new sections of 6-percent thickness (NACA 1-006 and NACA 2-006) are discussed in reference 1. The experimental results showed the new sections to have maximum lift coefficients at low speeds (Mach numbers less than 0.2) of the order of 1.3 as compared to values of about 0.8 which are characteristic of more conventional symmetrical airfoils of 6-percent thickness. This rather large gain in maximum lift was obtained at the expense of some reduction in the Mach number for drag divergence. On the basis of the results obtained for the NACA 1-006 and NACA 2-006, however, the supposition was made in reference 1 that it might be possible to derive other symmetrical airfoils of 6-percent thickness which would have maximum lift coefficients not much less than those of the NACA 1-006 and NACA 2-006 but which would have substantially higher drag divergence Mach numbers. The present investigation was undertaken to explore this possibility.

Two airfoils designated NACA 3-006 and NACA 4-006 have been derived according to the methods described in reference 1. These sections differ from the NACA 1-006 and NACA 2-006 in that the bluntness of their leading edges has been somewhat reduced. The results of a two-dimensional experimental investigation of the characteristics of these two sections at low and high subsonic speeds are presented herein together with ordinates and theoretical velocity-distribution data. Included in the low-speed results are data for Reynolds numbers as high as 9×10^6 and data for two locations of surface roughness.

SYMBOLS

| | |
|--------|--|
| c_l | section lift coefficient, $\frac{l}{qc}$ |
| l | section lift, lb/foot of span |
| c | airfoil chord, ft |
| q | free-stream dynamic pressure, lb/sq ft, $\rho V^2/2$ |
| V | free-stream velocity, ft/sec |
| ρ | free-stream mass density, slugs/cu ft |

| | |
|--------------|---|
| c_d | section drag coefficient, $\frac{d}{qc}$ |
| d | section drag, lb/foot of span |
| $c_{m_c/4}$ | section pitching-moment coefficient about quarter-chord point |
| $c_{m_{ac}}$ | section pitching-moment coefficient about aerodynamic center |
| α_0 | section angle of attack, deg |
| R | free-stream Reynolds number based on airfoil chord and free-stream velocity |
| x | distance along chord as measured from leading edge |
| y | distance measured normal to chord line |
| M | free-stream Mach number, $\frac{V}{a}$ |
| a | free-stream speed of sound, ft/sec |
| Δv_a | local velocity increment due to angle of attack |
| v | local velocity |
| ψ | airfoil design parameter (ref. 2) |

DERIVATION OF AIRFOILS

The choice of the NACA 1-006 and NACA 2-006 sections for experimental investigation in reference 1 rested upon the results of an analytical study of the effect of airfoil leading-edge shape on the low-speed maximum lift coefficient. This study was based on an empirical correlation between the theoretical airfoil pressure distribution and the experimental maximum lift coefficient as determined from tests of some 40 airfoils. With the use of this correlation and the airfoil theory of Theodorsen and Garrick (ref. 2), the effect of leading-edge bluntness on the low-speed maximum lift was systematically studied. The application of the Theodorsen-Garrick theory in this case involved the expression of the parameter ψ in terms of a specific function of the angular coordinates. The function contained two arbitrary constants. One of these constants controlled the airfoil thickness ratio while the other constant controlled

the airfoil thickness distribution and thus, for airfoils of a given thickness ratio, the pressure distribution and maximum lift coefficient. The value of the thickness-distribution parameter employed in deriving the NACA 1-006 section gave very nearly the highest predicted maximum lift to be expected of a 6-percent-thick section derived from the particular type of ψ -function employed. The value of the thickness-distribution parameter employed in deriving the NACA 2-006 gave an airfoil with a somewhat less blunt leading edge and a slightly reduced predicted maximum lift coefficient as compared to the NACA 1-006.

The two sections which form the subject of the present experimental investigation were derived with the use of the same function for the ψ -parameter as that employed in deriving the NACA 1-006 and NACA 2-006 sections. The values of the constant which controls the thickness distribution were chosen so that the leading edges of both of the sections of the present investigation were less blunt than those of the two sections considered in reference 1. The two sections derived are designated NACA 3-006 and NACA 4-006 where the digits 3 and 4 are merely identifying numbers and the 6 represents the maximum airfoil thickness ratio. Both sections are symmetrical with the leading edge of the NACA 4-006 being less blunt than that of the NACA 3-006. The values of the parameter ψ at the leading edge for the NACA 3-006 and NACA 4-006 sections are 0.124 and 0.097, respectively, which, according to figure 4 of reference 1, indicates that the low-speed maximum lift coefficient of the NACA 3-006 should be approximately 1.16 whereas that of the NACA 4-006 should be approximately 0.96.

The rear portions of the airfoils derived from the given expression for the distribution of the ψ -parameter are shown in reference 1 to be impractically thin. (The airfoils are shaped like a tadpole.) It was further pointed out in reference 1 that the shape of that portion of the airfoil behind the position of maximum thickness had no important effect on the pressure distribution at high lift coefficients. The portions of the NACA 1-006 and NACA 2-006 sections behind the maximum-thickness position were therefore formed, quite arbitrarily, by a straight-line fairing from the trailing edge to the point of tangency a short distance behind the position of maximum thickness. In an effort to obtain some further thickening of the rear portions of the NACA 3-006 and NACA 4-006 sections, that part of the airfoils extending from the position of maximum thickness to the trailing edge was made to conform to the shape given by the polynomial expression employed in reference 3 for determining the rear portions of the modified NACA 4-digit series sections. The first derivative was made continuous at that point where the front and rear portions of the airfoils were joined.

The ordinates and theoretical velocity-distribution data for the NACA 3-006 and NACA 4-006 sections are given in tables I and II. The method of employing velocity-distribution data in the form given to

calculate the pressure distribution at low speeds at any lift coefficient is discussed in reference 4. A comparison of the shapes of the NACA 3-006 and NACA 4-006 sections with those of the NACA 1-006, NACA 2-006, and NACA 64-006 sections is presented in figure 1.

APPARATUS AND TESTS

Wind Tunnel

The present investigation was conducted in the Langley low-turbulence pressure tunnel. The tunnel test section is 3 feet wide and $7\frac{1}{2}$ feet high. High subsonic speeds are attained in this tunnel by using Freon-12 as the testing medium at pressures below atmospheric, whereas low-speed tests are conducted with air as the testing medium with pressures ranging from below atmospheric to 150 pounds per square inch according to the Reynolds number desired. Reference 5 contains a more complete description of the tunnel while reference 6 describes more fully the use of Freon-12 as a testing medium.

Models and Measuring Equipment

The two-dimensional models used in the present investigation were made of steel machined to conform to the ordinates of the NACA 3-006 and NACA 4-006 airfoil sections as given in tables I and II, respectively. Each model had a 1-foot chord and was so mounted as to span the 3-foot dimension of the tunnel, one end being attached by a universal joint to the two-dimensional-tunnel semispan strain-gage-type balance in such a way as to cause no constraint in yaw or roll, while the other end was pivoted in a self-aligning bearing which restrained only lift and drag forces. This method of mounting the model enabled the semispan balance to measure one-half of the lift and drag forces and all of the pitching moment. A labyrinth-type seal was used where each end of the model extended through the tunnel wall to minimize any air-leakage effects through the slots in the tunnel wall. The mounting-configuration details are illustrated in figure 2 while figure 3 shows a model mounted in the tunnel test section.

Measurements of the lift and pitching moment were made with the semispan balance at both low and high subsonic Mach numbers. Because of the fact that the degree of accuracy of the balance does not permit reliable measurement of the low drags encountered at the lower Mach numbers, the more exact wake-survey method for measurement was used for Mach numbers below about 0.8. The wake-survey rake was located approximately 1 foot behind the trailing edge of the model. For the higher Mach number range, the wake-survey method requires a tedious point-by-point

measurement of the losses in the wake to evaluate the drag (see ref. 7 for a more complete discussion), so that the balance was employed for drag measurement. It has been shown in reference 1 that both methods of drag measurement are in close agreement for the higher Mach number range.

Tests

The low-speed tests consisted of measurements of the lift, drag, and pitching moment of the NACA 3-006 and NACA 4-006 airfoil sections at Reynolds numbers of approximately 3×10^6 , 6×10^6 , and 9×10^6 for the models in the smooth surface condition and at a Reynolds number of 6×10^6 for the models in the roughened surface condition. The angle-of-attack range investigated was from approximately -16° to 16° . Tunnel pressures were regulated up to 150 pounds per square inch so as to limit the Mach number to 0.2 or less while attaining the desired Reynolds number. Two locations for roughness were employed: one, the so-called standard type, where the upper and lower surfaces were roughened from the leading edge rearward 8 percent chord as measured along the surface, and the other where a quarter-inch-wide spanwise strip beginning at 0.05c was roughened. The roughness consisted of carborundum grains of approximately 0.004-inch diameter spread over a coat of shellac in such a manner as to cover from 5 to 10 percent of the specified area.

The high-speed tests also consisted of measurements of the lift, drag, and pitching-moment characteristics of the NACA 3-006 and NACA 4-006 airfoil sections. These tests were made in Freon-12 at a tunnel stagnation pressure of approximately 16 inches of mercury absolute at a Freon purity in excess of 95 percent by weight. Data were obtained for the model in the smooth surface condition only and for a Mach number range of from about 0.3 to the Mach number approximately 0.03 below that for a choking condition in the tunnel. The Reynolds number varied from about 3.0×10^6 for a Mach number of 0.35 to about 6.0×10^6 for Mach numbers up to about 0.85. The angle-of-attack range covered was from 0° to 7° .

CORRECTIONS

The data have been corrected for tunnel-wall effects, using the method discussed in reference 4 for low Mach number data and in reference 8 for high Mach number data. Angle-of-attack corrections involved were not applied because they were very small for the range of angle of attack investigated. The data recorded using Freon-12 gas as the testing medium were corrected and converted to equivalent air data by the methods of reference 6.

RESULTS AND DISCUSSION

Low-Speed Characteristics

Lift data as well as quarter-chord pitching-moment data for the NACA 3-006 and NACA 4-006 airfoil sections are presented in figures 4(a) and 5(a) while drag data along with pitching-moment data referred to the aerodynamic center are presented in figures 4(b) and 5(b) for three Reynolds numbers. Data are presented in figure 6 illustrating the effect of the leading-edge type of roughness as well as the strip type of roughness on the lift, drag, and quarter-chord pitching-moment characteristics of the sections investigated. A comparison of the lift and drag characteristics of the NACA 3-006 and NACA 4-006 sections with those of the NACA 1-006, NACA 2-006, and NACA 64-006 sections as taken from references 1 and 6 is presented in figure 7.

Lift.- As can be seen from figures 4(a) and 5(a), for a Reynolds number of 9×10^6 , the maximum section lift coefficient of the NACA 3-006 was 1.220 and that of the NACA 4-006 was 1.040. It is apparent from an examination of the positive and negative sides of the lift curve that the nose section of the NACA 4-006 was somewhat unsymmetrical as evidenced by the differences in the maximum section lift coefficients. A template check of the model leading-edge section revealed this to be true inasmuch as the lower surface appeared good while the upper surface did not quite conform to the contour of the template. Because of this difference, the maximum lift coefficients quoted for the section in this paper are averages of the values measured at positive and negative angles of attack.

Decreasing the Reynolds number from 9×10^6 to 3×10^6 resulted in a reduction of 0.14 and 0.19 in the maximum section lift coefficient for the NACA 3-006 and NACA 4-006 sections, respectively. The largest decrease occurred between Reynolds numbers of 6×10^6 and 3×10^6 with only a slight decrease from 9×10^6 to 6×10^6 . As compared to the NACA 1-006 and NACA 2-006 airfoil sections of reference 1, the airfoils of the present investigation exhibit a slightly larger scale effect. The nature of the stall for the NACA 3-006 section changes from a fairly gradual type at a Reynolds number of 9×10^6 to the abrupt type of stall at a Reynolds number of 3×10^6 , while the NACA 4-006 section retains the gradual type of stall for the Reynolds numbers investigated.

Examination of figure 7(a) reveals the NACA 3-006 and NACA 4-006 airfoil sections to have substantially higher maximum section lift coefficients than the NACA 64-006 section at a Reynolds number of 9×10^6 . The maximum section lift coefficient of the NACA 3-006 section

is approximately 49 percent higher while that of the NACA 4-006 is about 27 percent higher than that of the NACA 64-006. It is also apparent from figure 7(a) that both new airfoils have slightly higher lift-curve slopes than the NACA 64-006 section. Compared with the NACA 2-006 section, the sections of the present investigation have lower maximum section lift coefficients, with that of the NACA 4-006 section being approximately 0.24 lower. It is also apparent from figure 7 that the stall for all the airfoils is of a relatively gradual nature.

The addition of the so-called standard leading-edge type of roughness reduces the value of maximum section lift coefficient for the new airfoils to about 0.87 as shown in figure 6(a). Inasmuch as roughness does not affect the maximum lift of the NACA 64-006 (ref. 4), the airfoils of the present investigation do not appear to have any appreciable lift advantage in this roughened state. Addition of a quarter-inch-wide strip of roughness beginning at 0.05c, however, resulted in virtually the same maximum lift coefficient as for the smooth surface condition for both new airfoils. This indicates that it is necessary to keep no more than the first 5 percent of the upper and lower surfaces smooth to obtain the high maximum lift coefficients associated with the new sections.

Pitching moment.- The quarter-chord pitching-moment data of figures 4(a), 5(a), and 6(a) as well as the pitching moment referred to the aerodynamic center in figures 4(b) and 5(b) exhibit no unusual characteristics that warrant comment.

Drag.- It is seen in figures 4(b) and 5(b) that both the NACA 3-006 and the NACA 4-006 airfoil sections had minimum section drag coefficients of the order of 0.0055. The drag polar of the NACA 3-006 section is similar to those of the NACA 1-006 and NACA 2-006 sections of reference 1 in that a characteristic dip was present at section lift coefficients of ± 0.5 at which lift values the minimum drag occurred. This peculiarity, as pointed out in reference 1, may be due to the pressure gradient on one surface becoming less adverse and the relative extent of laminar flow on this surface increasing as the lift coefficient is varied from zero. The previously noted asymmetry in the leading-edge contour of the NACA 4-006 section model is again apparent in the drag data. The NACA 4-006 exhibits a drag polar rather similar to that of a comparable NACA four-digit series airfoil section and contains no very pronounced dip. This is as would be expected since the velocity distribution of the NACA 4-006 is not greatly different from that of the NACA 0006 (see table II and ref. 4). The NACA 4-006 has a zero-lift section drag coefficient about 0.0011 lower than that of the NACA 3-006 section. The effect of increasing the Reynolds number from 3×10^6 to 9×10^6 was favorable in that low drags were maintained to higher lift coefficients.

It is evident from figure 7(b) that although the NACA 64-006 has a minimum drag coefficient of the order of 0.002 lower than the NACA 3-006

and NACA 4-006 sections at a Reynolds number of 9×10^6 , the new airfoils have lower drags for lift coefficients above 0.4. From this figure it is further shown that the NACA 4-006 airfoil section has lower drag coefficients than the NACA 3-006 airfoil section for lift coefficients up to about 0.4, above which value both sections have similar drag values. Also apparent from figure 7(b) is the fact that the NACA 4-006 section which is the least blunt of the new sections has the lowest minimum drag in the range of lift coefficient from about -0.2 to 0.2.

The application of leading-edge roughness resulted in increased drag throughout the lift range for both new airfoils as seen in figures 6(b) and 6(c). Both the NACA 3-006 and NACA 4-006 sections with a quarter-inch-wide strip of roughness starting at 0.05c had approximately the same minimum drag as for the leading-edge roughness configuration. The significant difference in drag resulting from use of the roughness at 0.05c as compared to leading-edge roughness was that relatively low drags were maintained to higher values of lift with the strip type of roughness. The application of leading-edge roughness resulted in approximately the same minimum drag for the sections under investigation as for the NACA 64-006 section (ref. 4) but for lift coefficients above about 0.3 the new sections exhibited lower drags.

High-Speed Characteristics

The lift, pitching-moment, and drag data for the NACA 3-006 and NACA 4-006 airfoil sections have been plotted against Mach number for various angles of attack in figures 8, 9, and 10, respectively. Data are presented up to a Mach number no higher than 0.03 less than that for tunnel choking. Figure 11 shows a comparison of drag characteristics against Mach number for the two airfoils of the present investigation and the NACA 1-006, NACA 2-006, and NACA 64-006 sections from reference 1. The data of figures 8, 9, and 10 have also been cross-plotted so as to present lift against section angle of attack, and pitching moment and drag against lift at different Mach numbers in figures 12, 13, and 14, respectively. Figures 12 and 13 also include data for the NACA 64-006 airfoil section as taken from reference 1, while figure 14 includes data for the NACA 1-006, NACA 2-006, and NACA 64-006 sections as taken from reference 1.

Lift.- As can be seen from the data of figure 8 there appear to be no very large differences in the high-speed lift characteristics of the NACA 3-006 and NACA 4-006 sections. Examination of figure 12 reveals the NACA 3-006 and NACA 4-006 airfoil sections to have about the same lift characteristics as the NACA 64-006 section for Mach numbers up to 0.65 for all angles of attack investigated. Since tunnel limitations restricted the angle of attack attainable at the higher subsonic Mach numbers, a maximum-lift comparison cannot be made but indications are

that the NACA 64-006 would have a higher maximum lift coefficient than the new airfoils above a Mach number of 0.65.

Pitching moment.- The quarter-chord pitching moments for the new sections as plotted in figure 9 show no significant differences between the two sections investigated. A comparison of the pitching-moment data plotted against lift coefficient for different Mach numbers with similar data from reference 1 for the NACA 64-006 section (fig. 13) reveals all three sections to have essentially the same pitching-moment characteristics.

Drag.- The drag characteristics of figure 10 indicate that, of the two airfoil sections of the present investigation, the NACA 4-006 section has slightly higher Mach numbers corresponding to drag divergence for the angles of attack investigated. A comparison of the variation in drag with Mach number for the NACA 3-006 and NACA 4-006 sections with similar data for the NACA 1-006, NACA 2-006, and NACA 64-006 sections is presented in figure 11 for various angles of attack. It is immediately apparent from these results that the drag characteristics of the NACA 3-006 and NACA 4-006 represent a substantial improvement over those of the NACA 1-006 and NACA 2-006. It can also be seen from figure 11 that, at zero angle of attack, the NACA 4-006 and NACA 64-006 sections have very similar drag characteristics, and that the drag coefficients of both of the new sections are considerably lower than those of the NACA 64-006 section at angles of attack of 4° and 6° for Mach numbers up to about 0.65. For Mach numbers above 0.65 there are no very large differences between the drag characteristics of the NACA 3-006 and NACA 4-006 sections and those of the NACA 64-006 section.

Examination of the same drag data plotted in polar form (fig. 14) again shows the very marked improvement in the drag characteristics of the NACA 3-006 and NACA 4-006 sections as compared to the NACA 1-006 and NACA 2-006 sections. The results presented in figure 14 further show that the sections of the present investigation have as good or better drag characteristics as those of the NACA 64-006 section through the entire range of lift coefficients investigated up to Mach numbers of the order of 0.65. For lift coefficients less than 0.4 the NACA 3-006, NACA 4-006, and NACA 64-006 sections had essentially the same drag characteristics up to a Mach number of 0.75. In general, at Mach numbers above about 0.65, the NACA 64-006 section had somewhat lower drags than the two new sections for lift coefficients above a certain value which decreased as the Mach number increased. This apparent inconsistency with the data presented at constant angles of attack in figure 11 results from the fact that higher lift coefficients are measured for the NACA 64-006 than for the new sections for the higher angles of attack at Mach numbers above 0.65.

CONCLUDING REMARKS

An investigation has been made at both high and low subsonic Mach numbers of two symmetrical 6-percent-thick airfoil sections derived to have high maximum lift at low speeds. These sections differ from previously investigated sections of the same family in that the bluntness of their leading edges has been somewhat reduced. The low-speed portion of the investigation was made at Reynolds numbers of 3×10^6 , 6×10^6 , and 9×10^6 for Mach numbers less than 0.2. The high-speed investigation consisted of tests through a Mach number range extending from about 0.3 to tunnel choking. The corresponding Reynolds number range was from 3×10^6 to 6×10^6 . The following conclusions can be drawn from this investigation:

1. Both new airfoil sections had low-speed maximum section lift coefficients higher than the NACA 64-006, one being 1.220 and the other being 1.040 as compared to 0.82 for the NACA 64-006. Application of the leading-edge type of roughness caused reductions in the value of maximum lift for the new airfoils to approximately the same value as for other 6-percent-thick airfoil sections, whereas application of roughness beginning at 0.05 chord resulted in the same maximum lift as for the airfoil in the smooth condition.

2. The drag characteristics at high subsonic speeds of the two sections showed a marked improvement over those of previously investigated blunt-nose airfoils of the same family. For Mach numbers from 0.30 to 0.65, the drag polars of the two new sections had as good or better characteristics as those of the NACA 64-006 section. At Mach numbers above about 0.65 the NACA 64-006 section had somewhat lower drags than the two new sections for lift coefficients above a certain value which decreased as the Mach number increased.

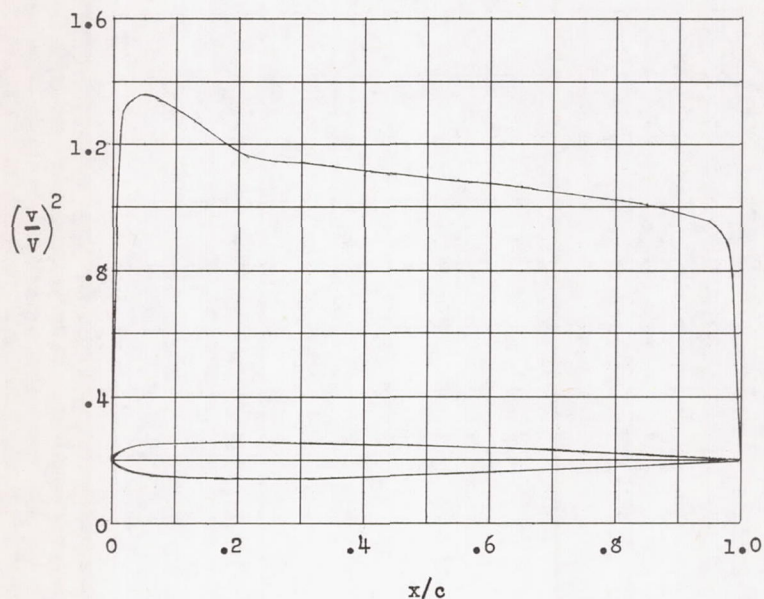
Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

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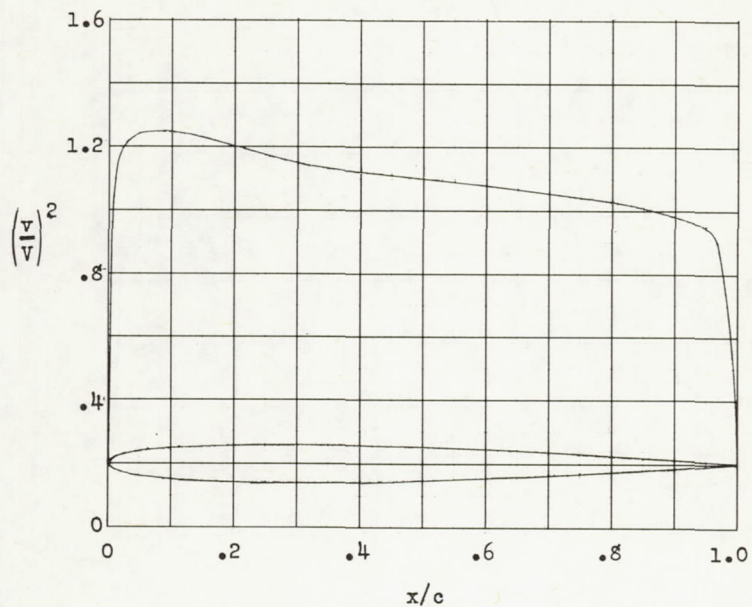
TABLE I

ORDINATES AND VELOCITY-DISTRIBUTION DATA FOR THE
NACA 3-006 AIRFOIL SECTION



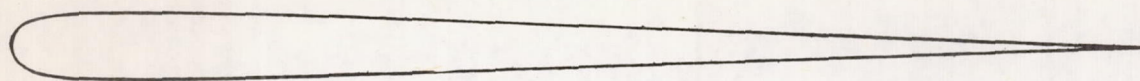
| x (percent c) | y (percent c) | $(v/v)^2$ | v/v | $\Delta v_a/v$ at $c_l=1.0$ |
|------------------------------|------------------|-----------|-------|-----------------------------------|
| 0 | 0 | 0 | 0 | 2.805 |
| .520 | .866 | .912 | .955 | 1.834 |
| 2.082 | 1.650 | 1.323 | 1.150 | 1.098 |
| 4.682 | 2.283 | 1.359 | 1.166 | .735 |
| 8.310 | 2.722 | 1.335 | 1.155 | .538 |
| 12.931 | 2.951 | 1.274 | 1.129 | .413 |
| 18.484 | 3.000 | 1.192 | 1.092 | .325 |
| 20.00 | 2.998 | 1.172 | 1.083 | .308 |
| 25.00 | 2.975 | 1.142 | 1.069 | .265 |
| 30.00 | 2.922 | 1.139 | 1.067 | .234 |
| 35.00 | 2.843 | 1.133 | 1.064 | .208 |
| 40.00 | 2.738 | 1.114 | 1.055 | .186 |
| 45.00 | 2.610 | 1.104 | 1.051 | .166 |
| 50.00 | 2.459 | 1.093 | 1.045 | .150 |
| 55.00 | 2.287 | 1.084 | 1.041 | .136 |
| 60.00 | 2.096 | 1.073 | 1.036 | .122 |
| 65.00 | 1.887 | 1.062 | 1.031 | .109 |
| 70.00 | 1.662 | 1.046 | 1.023 | .097 |
| 75.00 | 1.423 | 1.032 | 1.016 | .085 |
| 80.00 | 1.170 | 1.018 | 1.009 | .073 |
| 85.00 | .906 | 1.005 | 1.002 | .061 |
| 90.00 | .631 | .979 | .989 | .047 |
| 95.00 | .350 | .952 | .976 | .032 |
| 100.00 | .060 | 0 | 0 | 0 |
| L.E. radius: 0.761 percent c | | | | |

TABLE II
ORDINATES AND VELOCITY-DISTRIBUTION DATA FOR THE
NACA 4-006 AIRFOIL SECTION

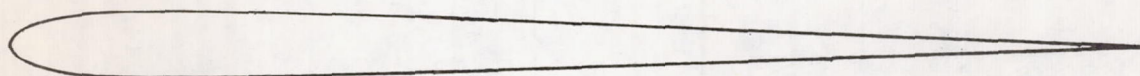


| x (percent c) | y (percent c) | $(v/v)^2$ | v/v | $\Delta v_a/V$ at $c_l=1.0$ |
|------------------|------------------|-----------|-------|-----------------------------------|
| 0 | 0 | 0 | 0 | 3.429 |
| .562 | .702 | .961 | .980 | 1.887 |
| 2.227 | 1.364 | 1.198 | 1.095 | 1.048 |
| 4.994 | 1.947 | 1.240 | 1.114 | .703 |
| 8.782 | 2.421 | 1.246 | 1.116 | .521 |
| 13.528 | 2.762 | 1.238 | 1.113 | .408 |
| 19.141 | 2.956 | 1.207 | 1.099 | .327 |
| 25.506 | 3.000 | 1.164 | 1.079 | .267 |
| 30.00 | 2.985 | 1.144 | 1.070 | .237 |
| 35.00 | 2.937 | 1.134 | 1.065 | .211 |
| 40.00 | 2.855 | 1.125 | 1.061 | .189 |
| 45.00 | 2.741 | 1.116 | 1.056 | .170 |
| 50.00 | 2.600 | 1.107 | 1.052 | .153 |
| 55.00 | 2.432 | 1.094 | 1.046 | .138 |
| 60.00 | 2.239 | 1.080 | 1.039 | .123 |
| 65.00 | 2.024 | 1.068 | 1.033 | .110 |
| 70.00 | 1.788 | 1.052 | 1.026 | .098 |
| 75.00 | 1.530 | 1.040 | 1.020 | .086 |
| 80.00 | 1.263 | 1.027 | 1.013 | .073 |
| 85.00 | .979 | 1.009 | 1.004 | .061 |
| 90.00 | .681 | .980 | .990 | .048 |
| 95.00 | .375 | .952 | .976 | .032 |
| 100.00 | .060 | 0 | 0 | 0 |

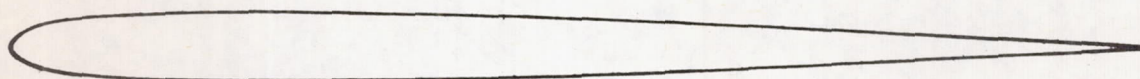
L.E. radius: 0.56 percent c



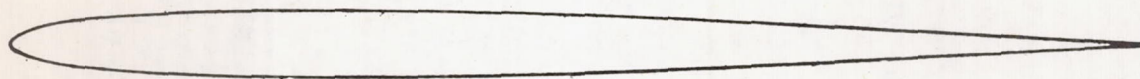
NACA 1-006



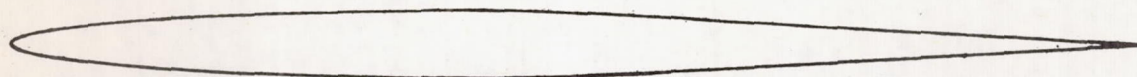
NACA 2-006



NACA 3-006



NACA 4-006



NACA 64-006

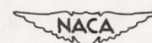


Figure 1.- Comparison of the shapes of the NACA 1-006, NACA 2-006, NACA 3-006, NACA 4-006, and NACA 64-006 airfoil sections.

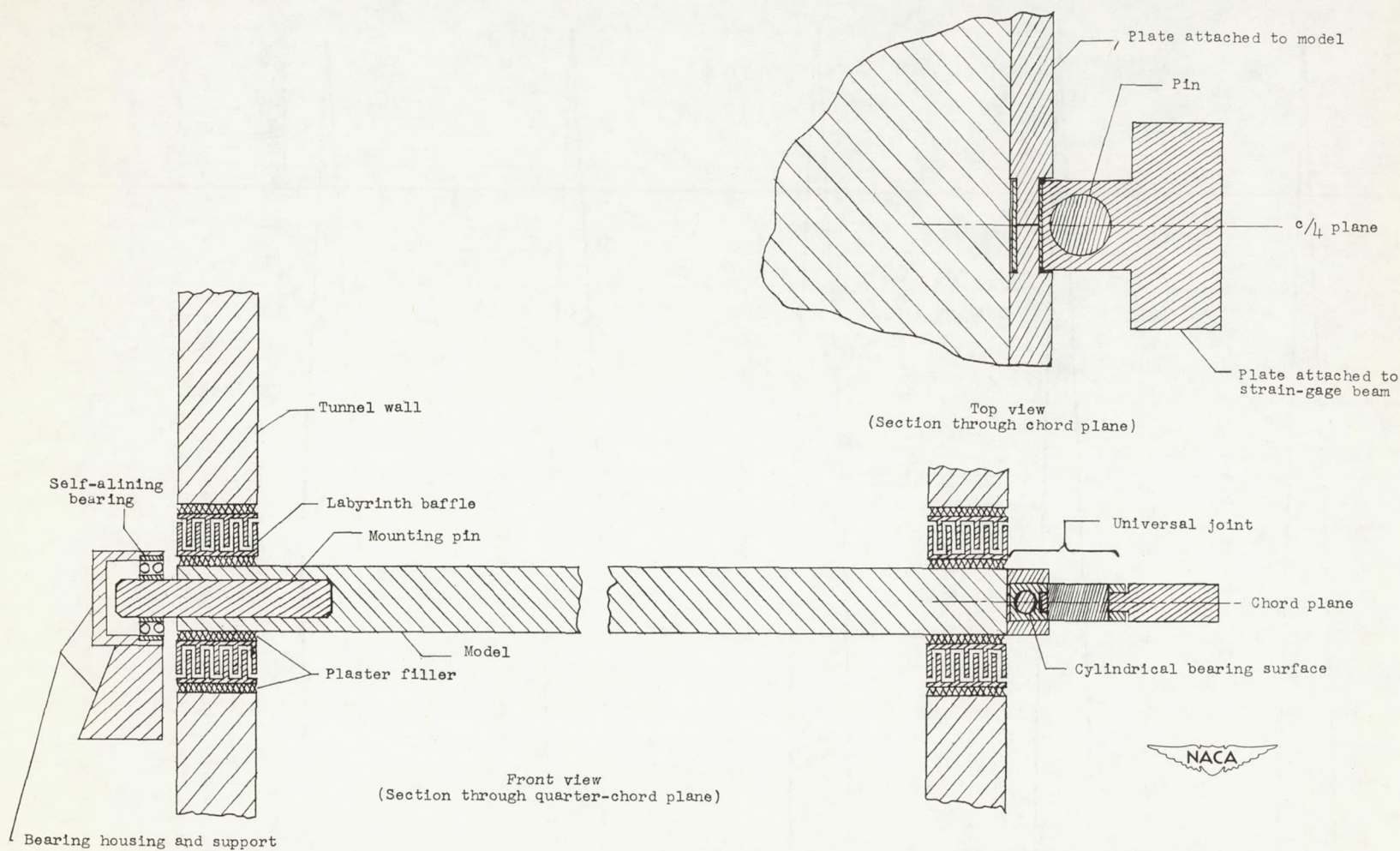


Figure 2.- Schematic drawing of model mounted in tunnel for force and moment measurements employing strain-gage balance.

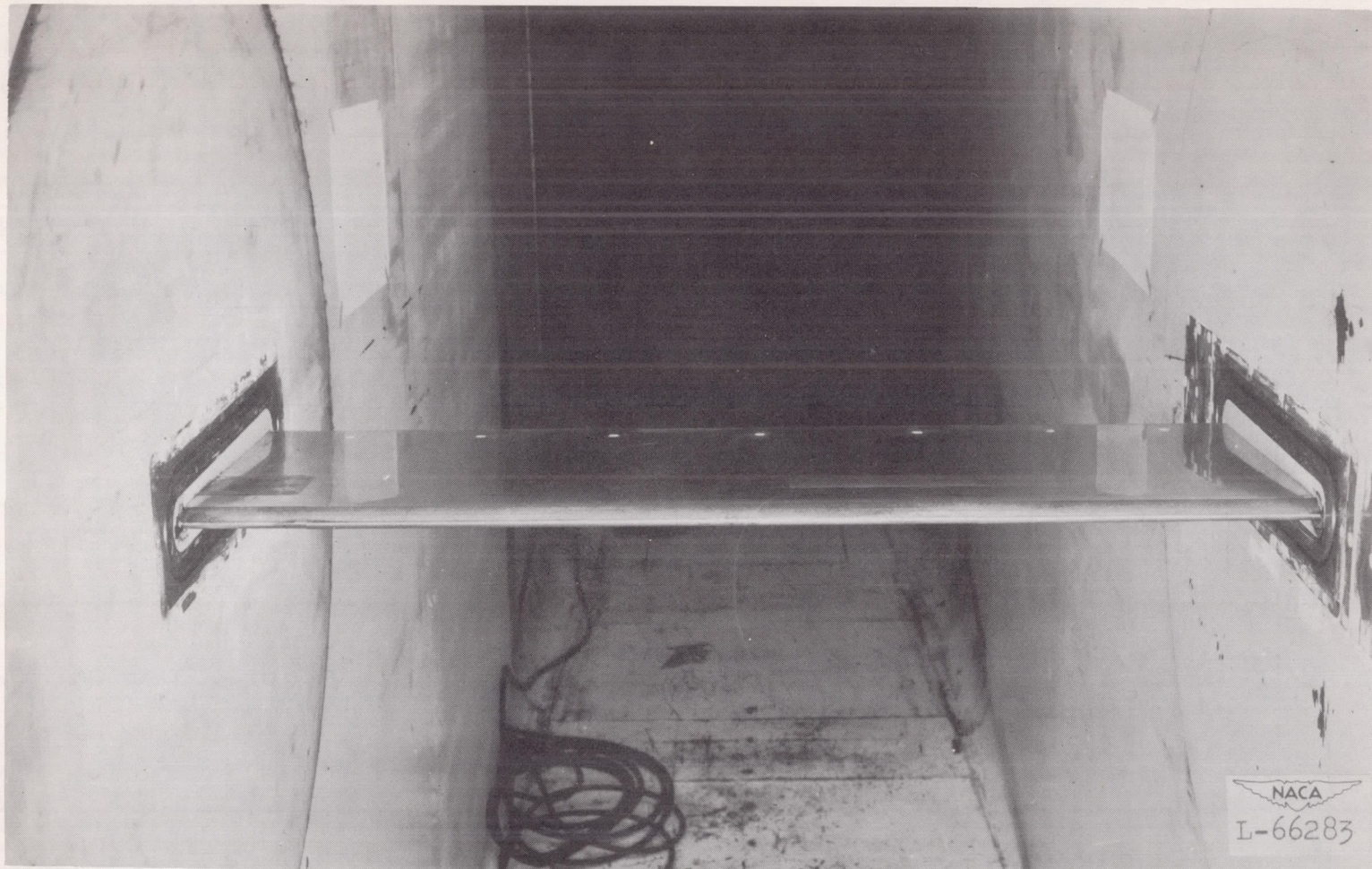
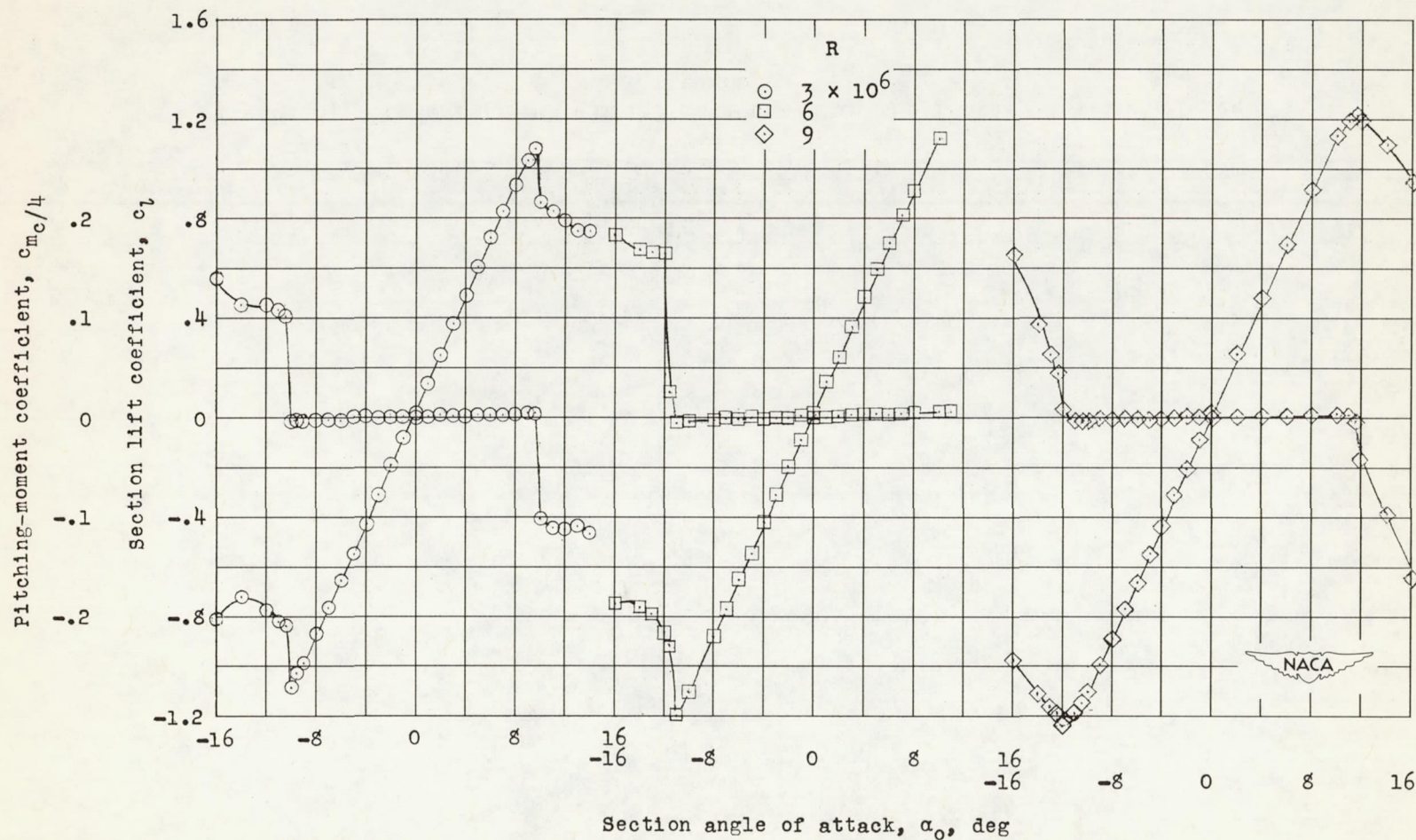
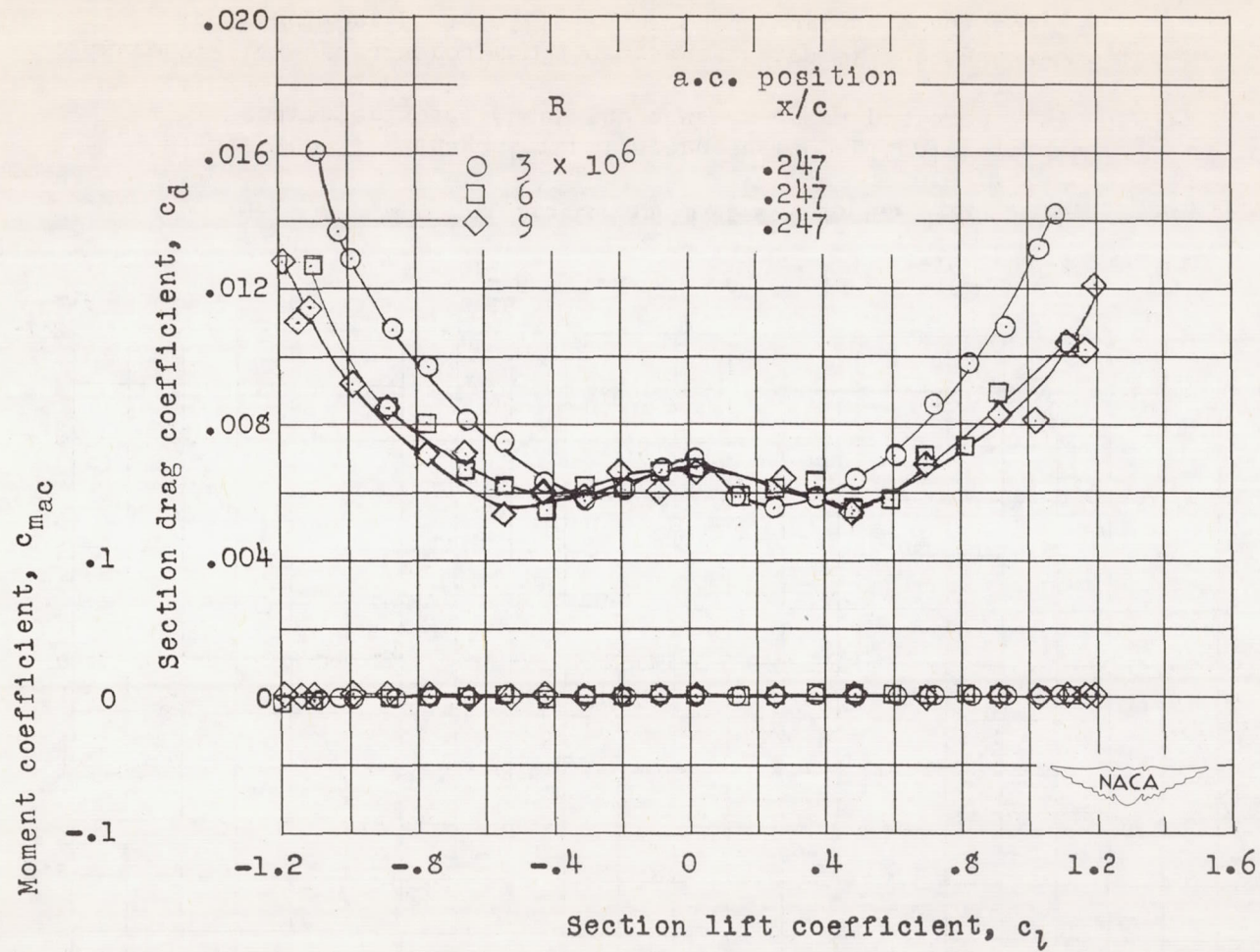


Figure 3.- Photograph of a model as mounted in the Langley low-turbulence tunnel.



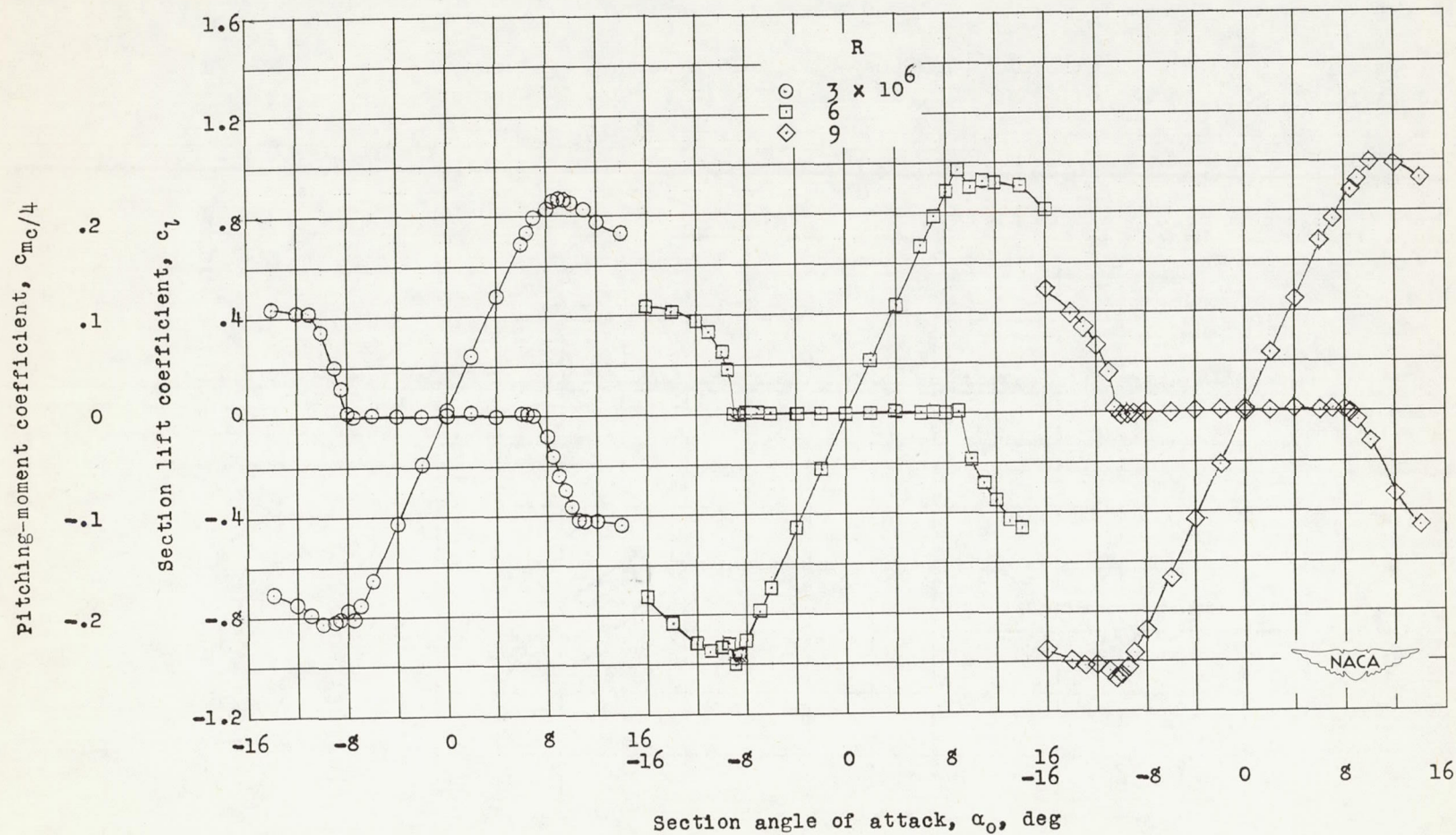
(a) Section lift characteristics and section pitching-moment characteristics about the quarter-chord position.

Figure 4.- Low-speed aerodynamic characteristics of the NACA 3-006 airfoil section; plain airfoil in smooth surface condition.



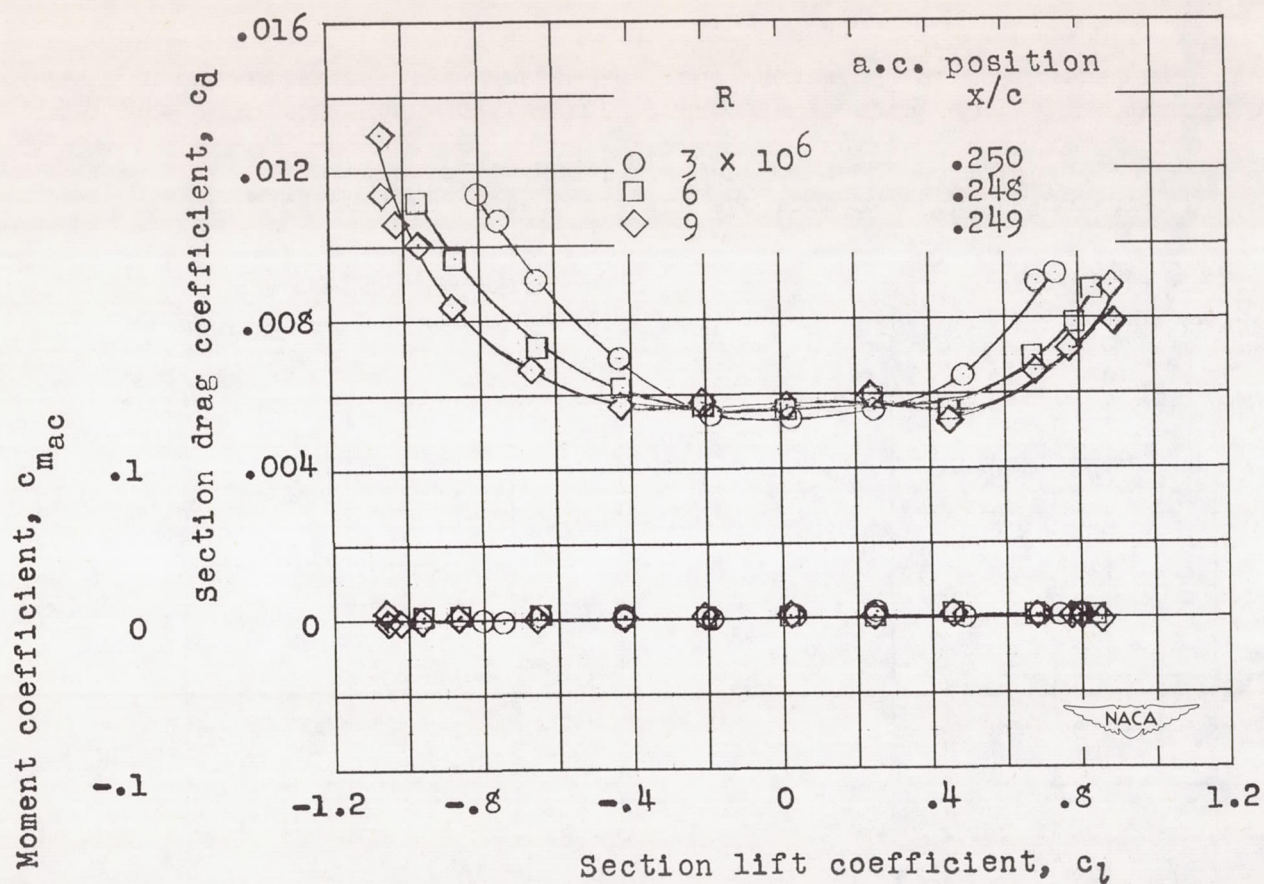
(b) Section drag characteristics and section pitching-moment characteristics about the aerodynamic center.

Figure 4.- Concluded.



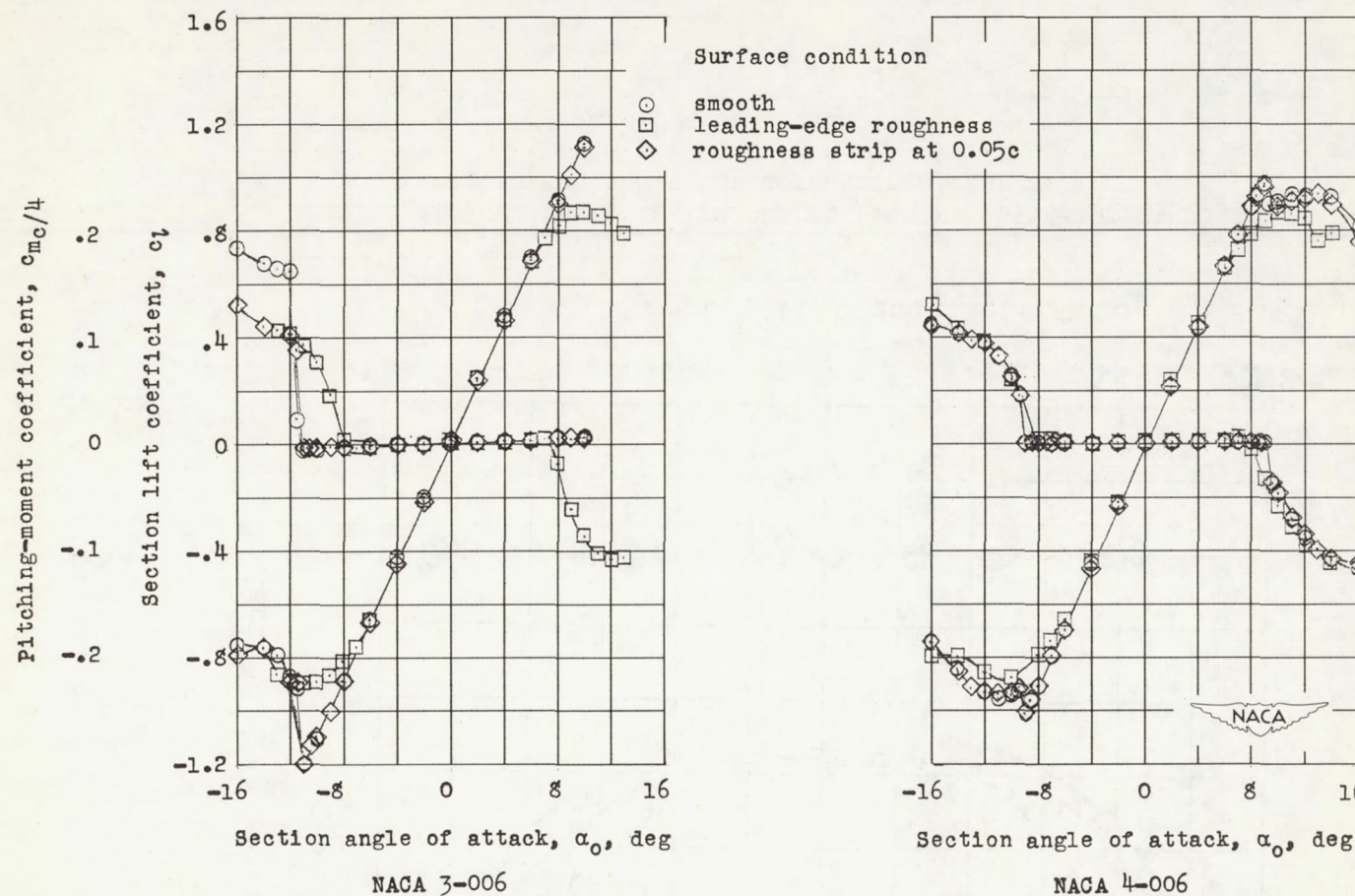
(a) Section lift characteristics and section pitching-moment characteristics about the quarter-chord position.

Figure 5.- Low-speed aerodynamic characteristics of the NACA 4-006 airfoil section; plain airfoil in smooth surface condition.



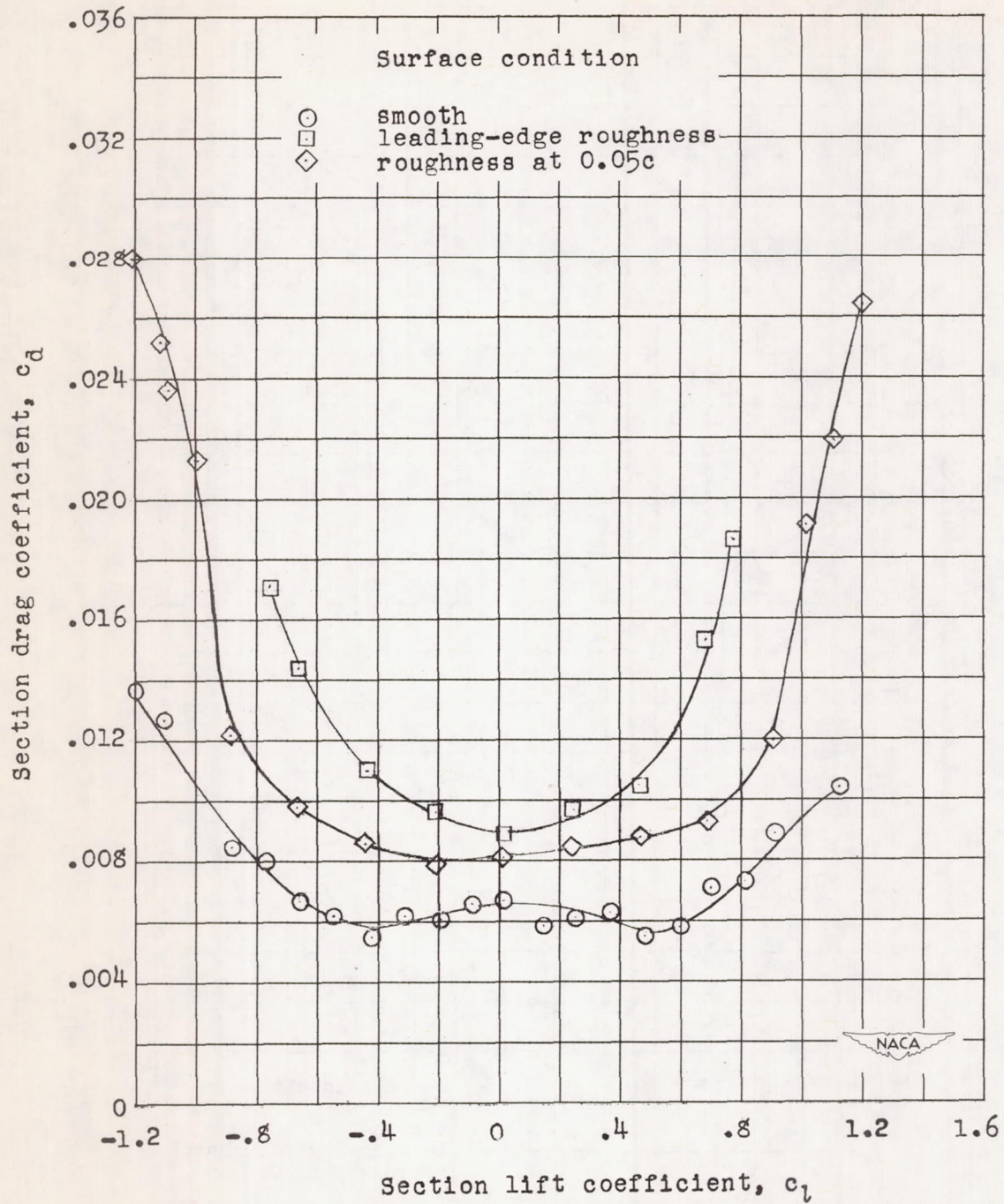
(b) Section drag characteristics and section pitching-moment characteristics about the aerodynamic center.

Figure 5.- Concluded.



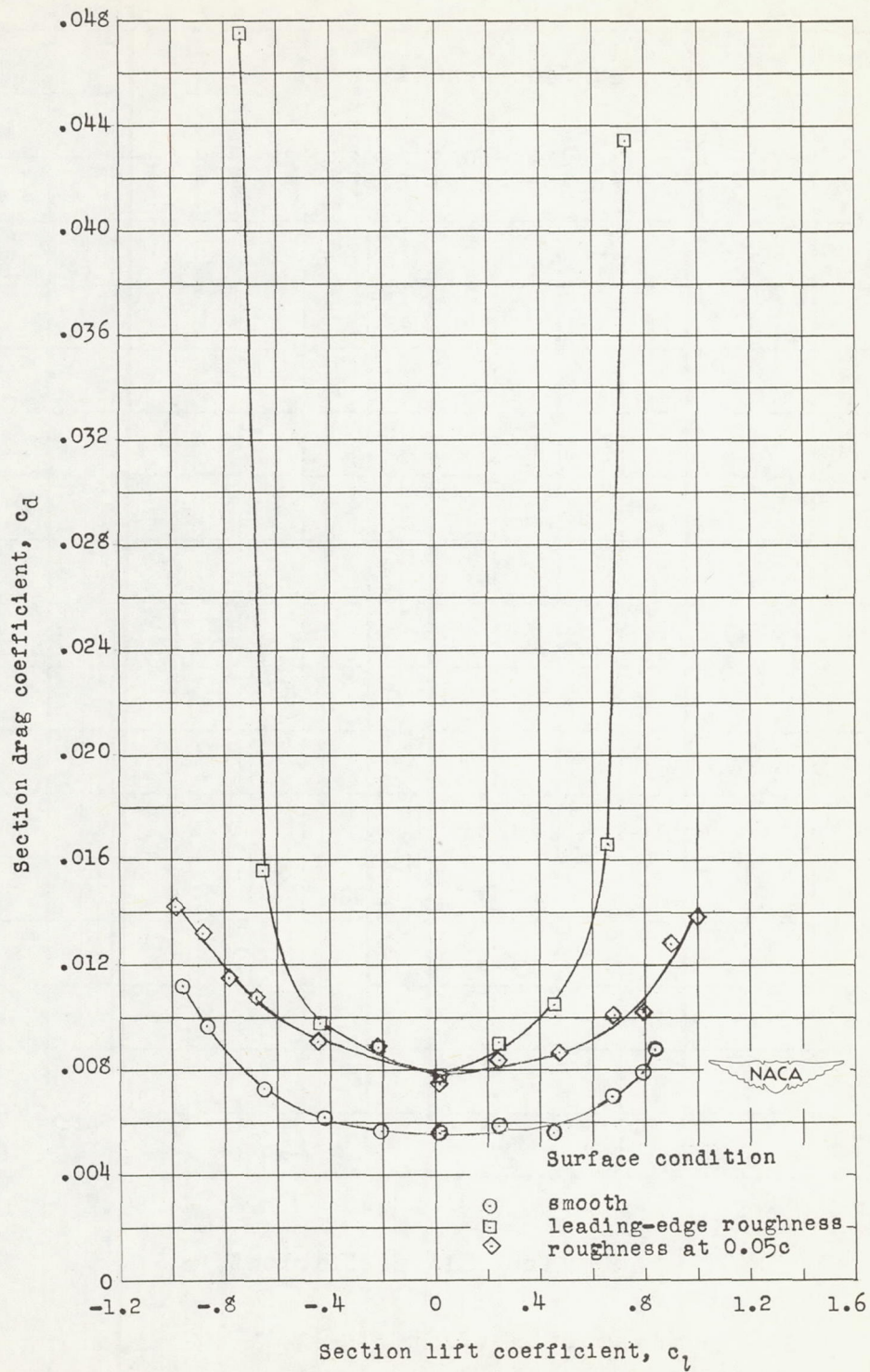
(a) Section lift characteristics and section pitching-moment characteristics about the quarter-chord position.

Figure 6.- Effect of roughness and roughness location on the aerodynamic characteristics of the NACA 3-006 and NACA 4-006 airfoil sections.
 $R = 6 \times 10^6$.



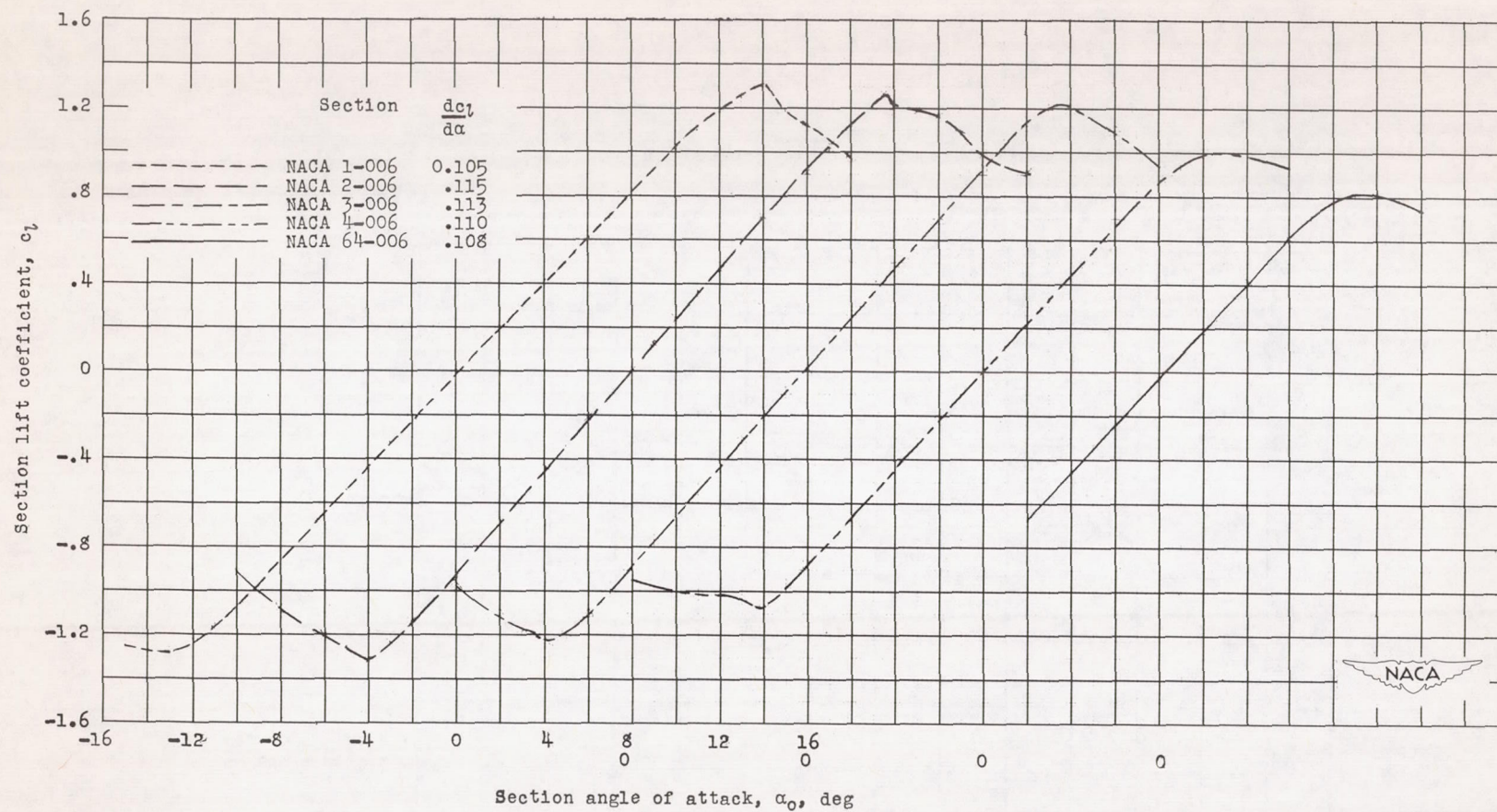
(b) Section drag characteristics of the NACA 3-006 airfoil section.

Figure 6.- Continued.



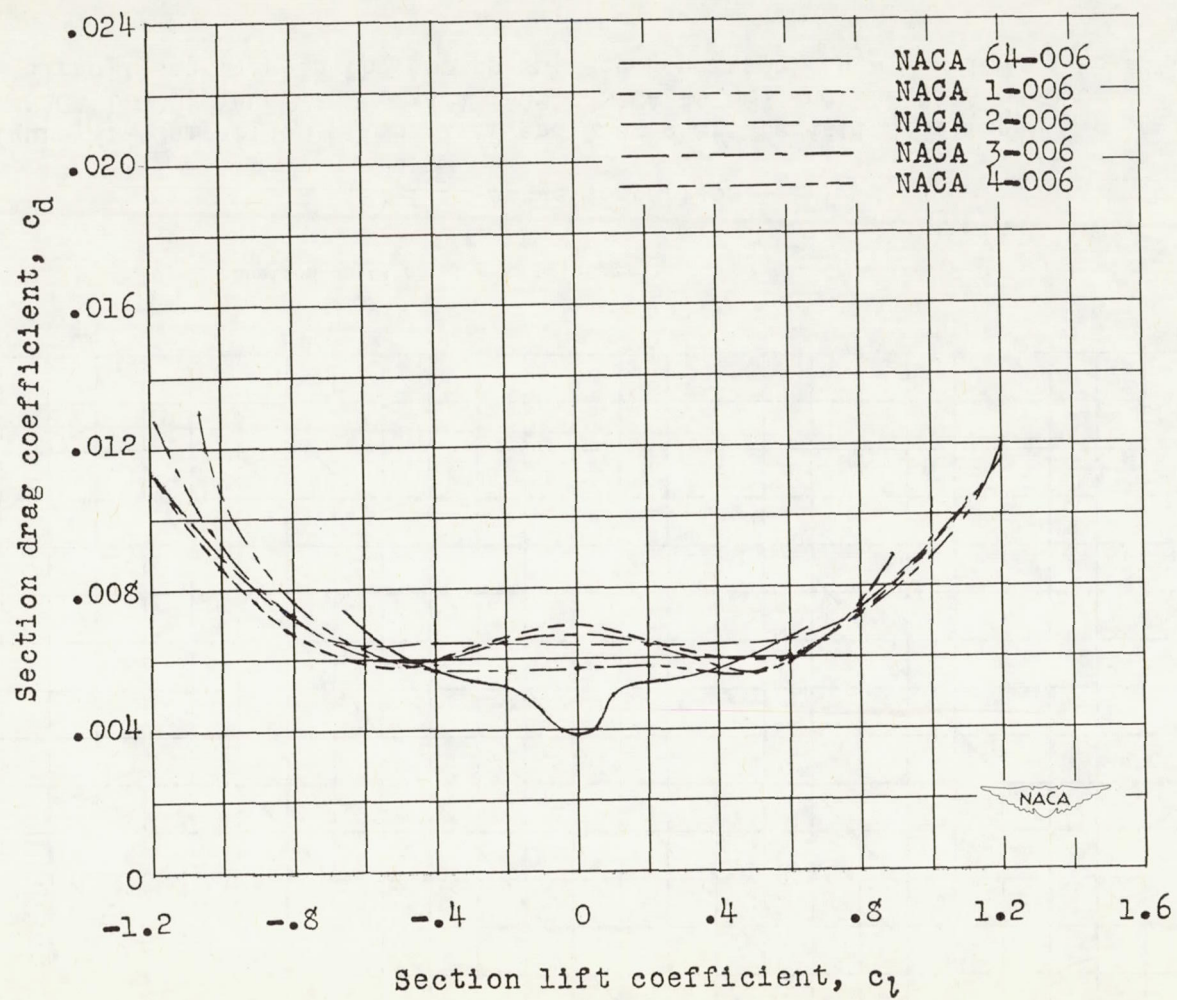
(c) Section drag characteristics of the NACA 4-006 airfoil section.

Figure 6.- Concluded.



(a) Lift-curve comparison.

Figure 7.- Comparison of the lift and drag characteristics of the NACA 1-006, NACA 2-006, NACA 3-006, NACA 4-006, and the NACA 64-006 airfoil sections in the smooth surface condition. $R = 9 \times 10^6$.



(b) Drag polar comparison.

Figure 7.- Concluded.

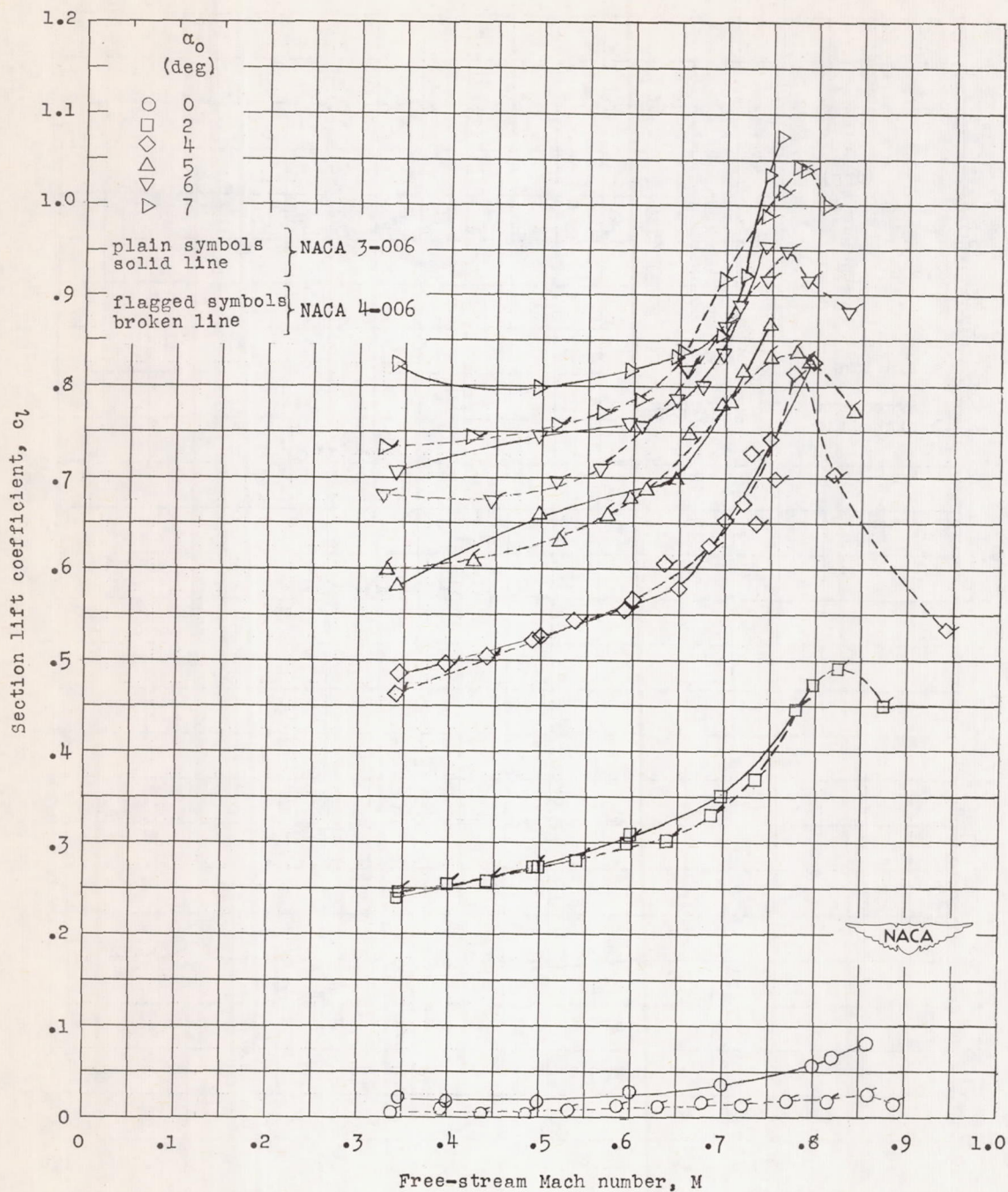


Figure 8.- Variation of section lift coefficient with free-stream Mach number for the NACA 3-006 and NACA 4-006 airfoil sections in a smooth surface condition at several angles of attack.

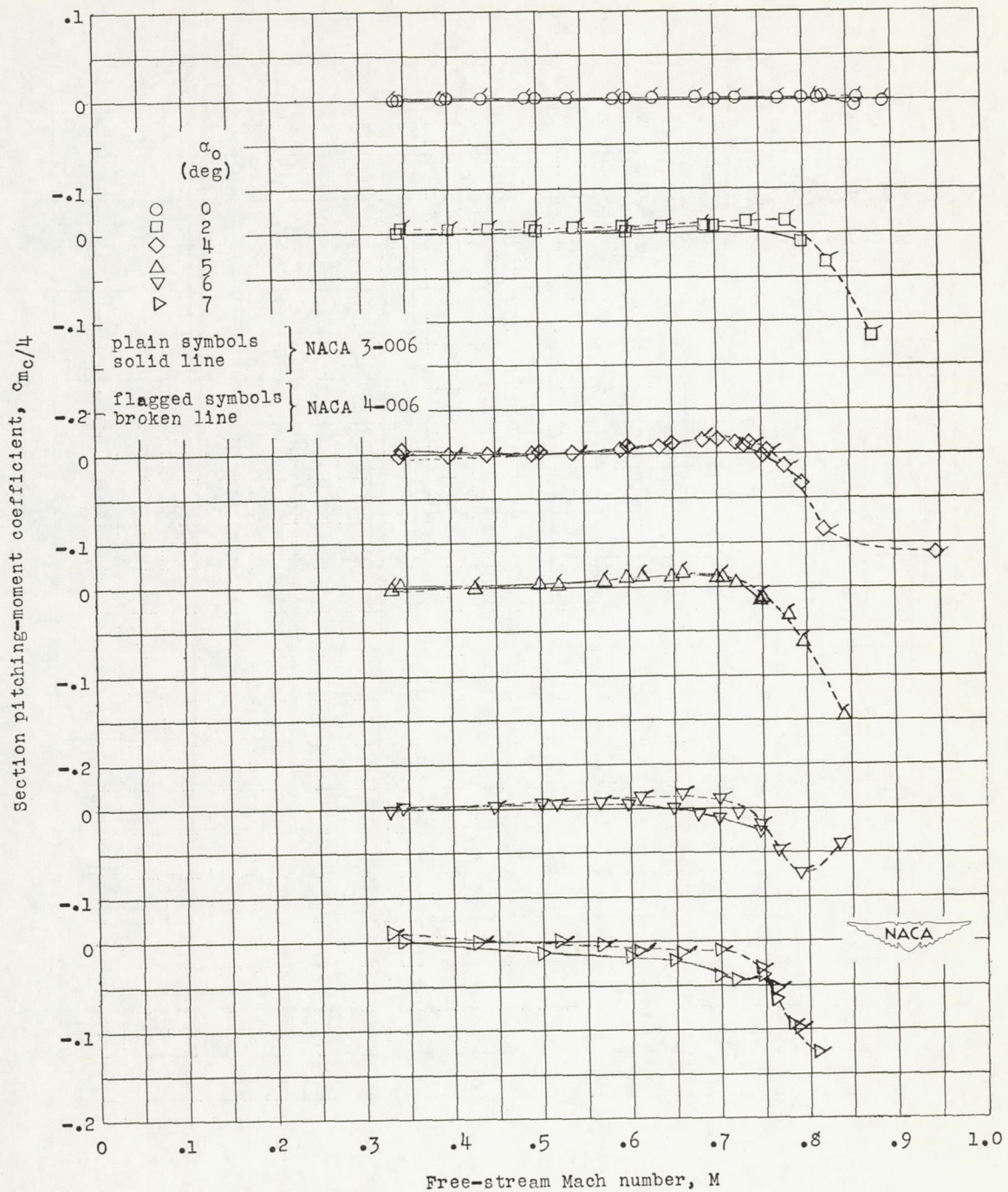
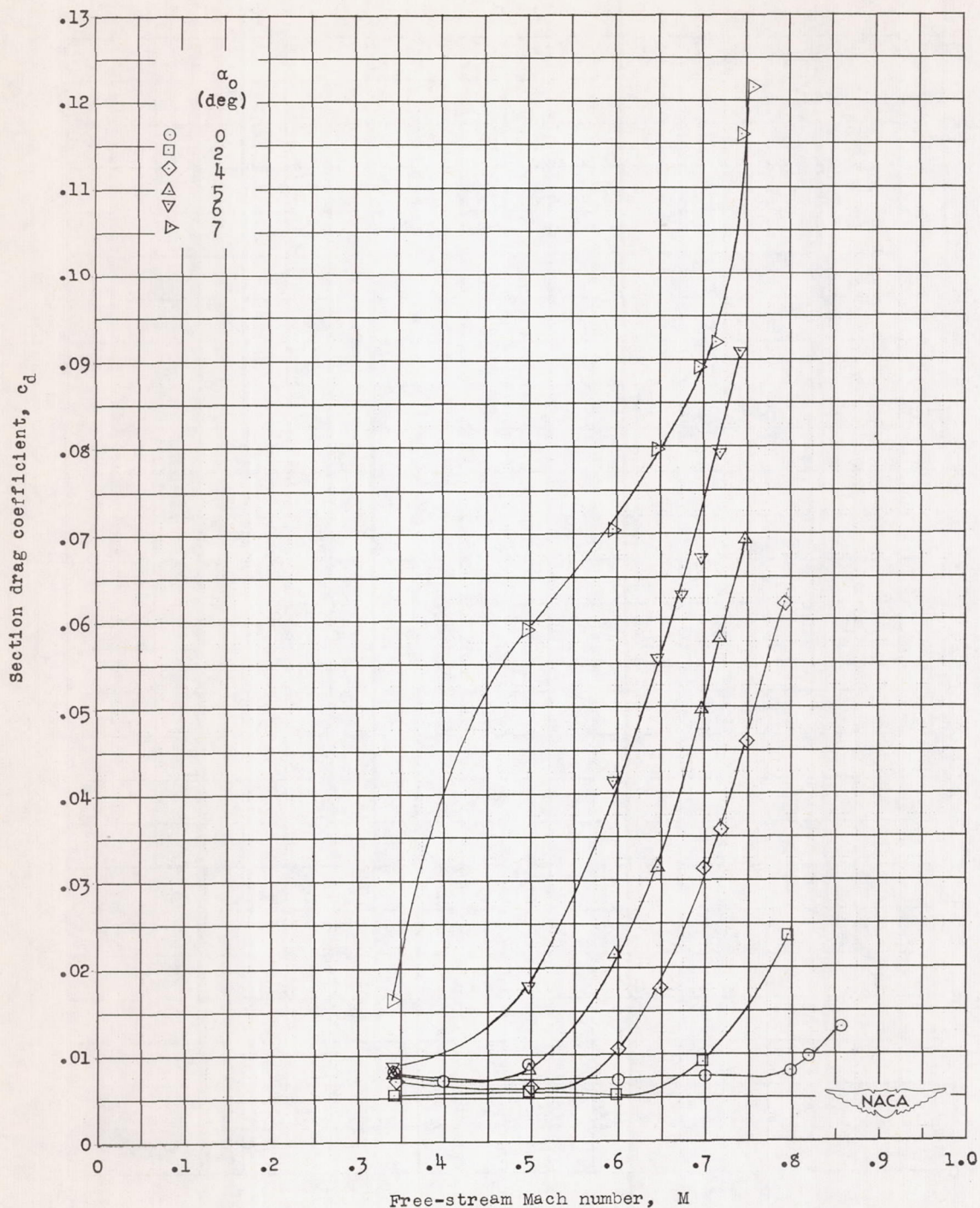
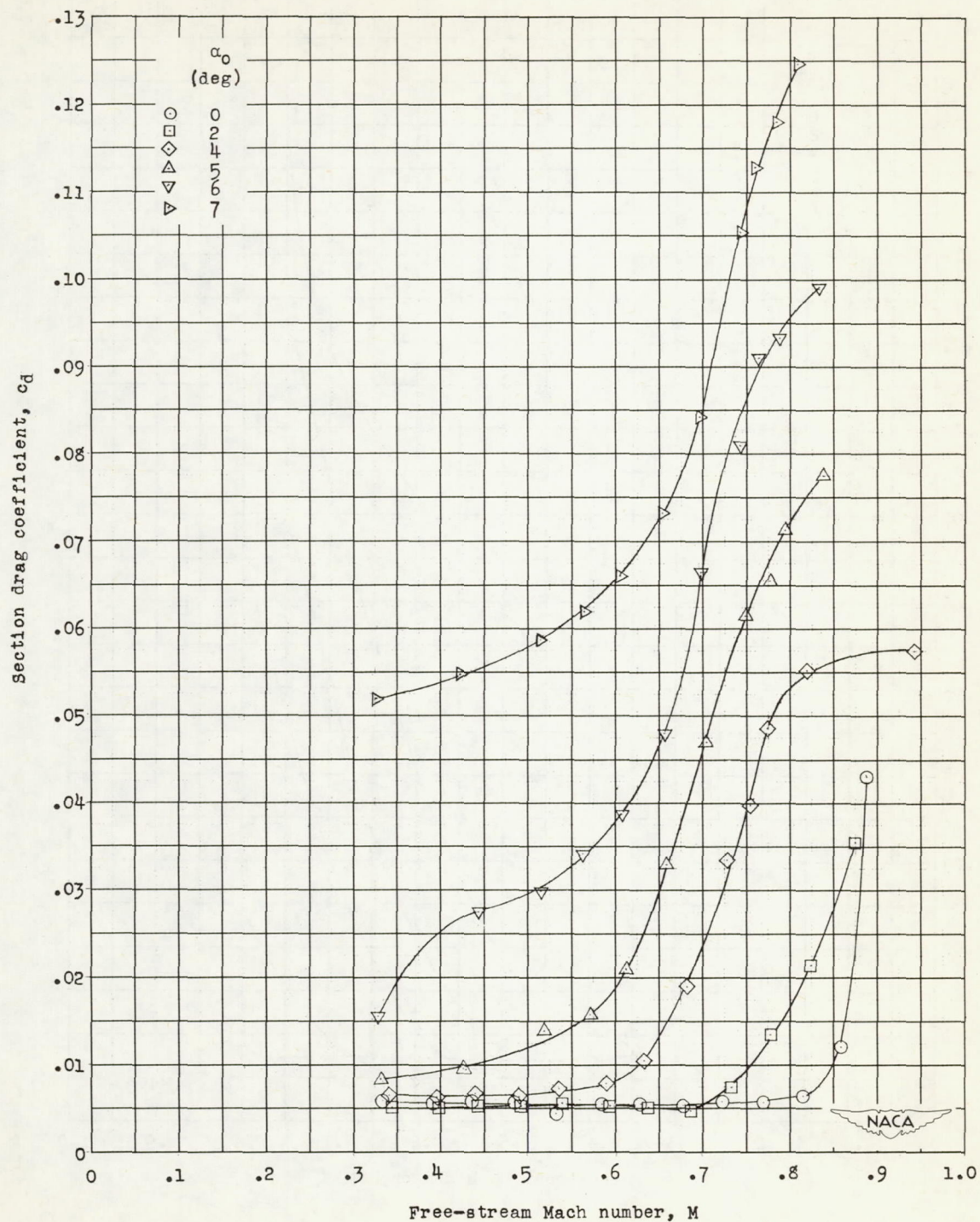


Figure 9.- Variation of section pitching-moment coefficient with free-stream Mach number for the NACA 3-006 and NACA 4-006 airfoil sections in a smooth surface condition at several angles of attack.



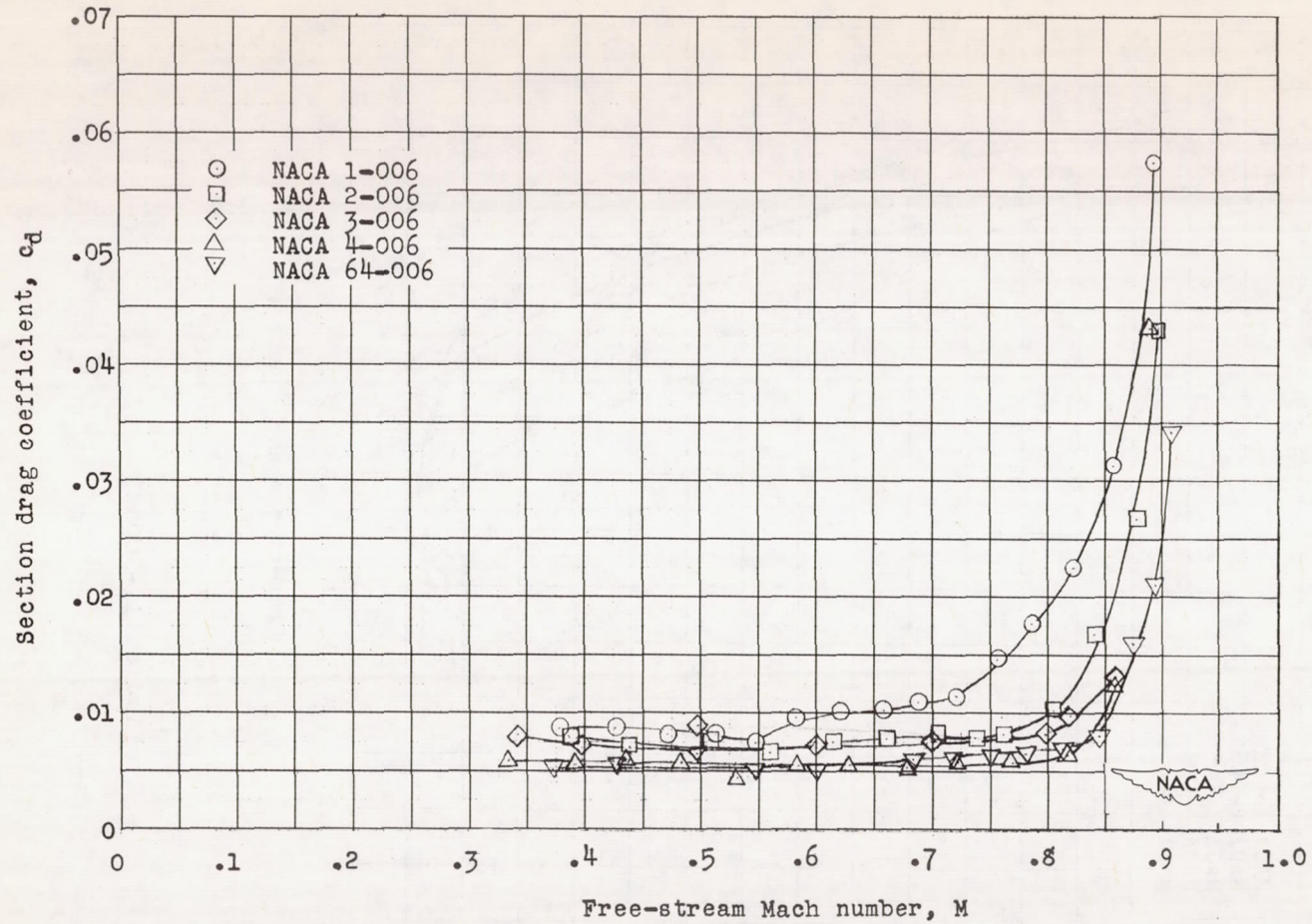
(a) NACA 3-006 airfoil section.

Figure 10.- Variation of section drag coefficient with free-stream Mach number for the NACA 3-006 and NACA 4-006 airfoil sections in a smooth surface condition at several angles of attack.



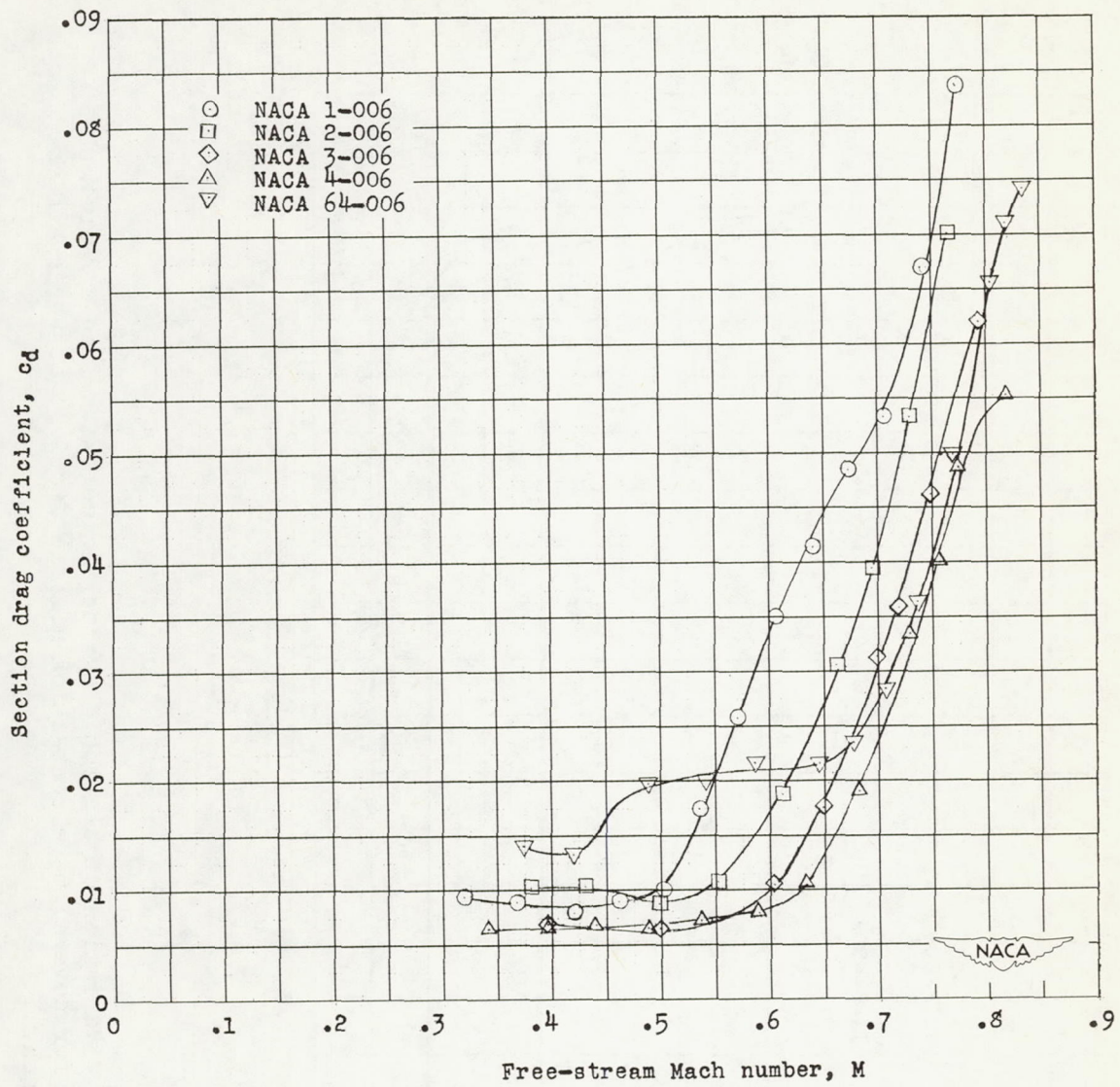
(b) NACA 4-006 airfoil section.

Figure 10.- Concluded.



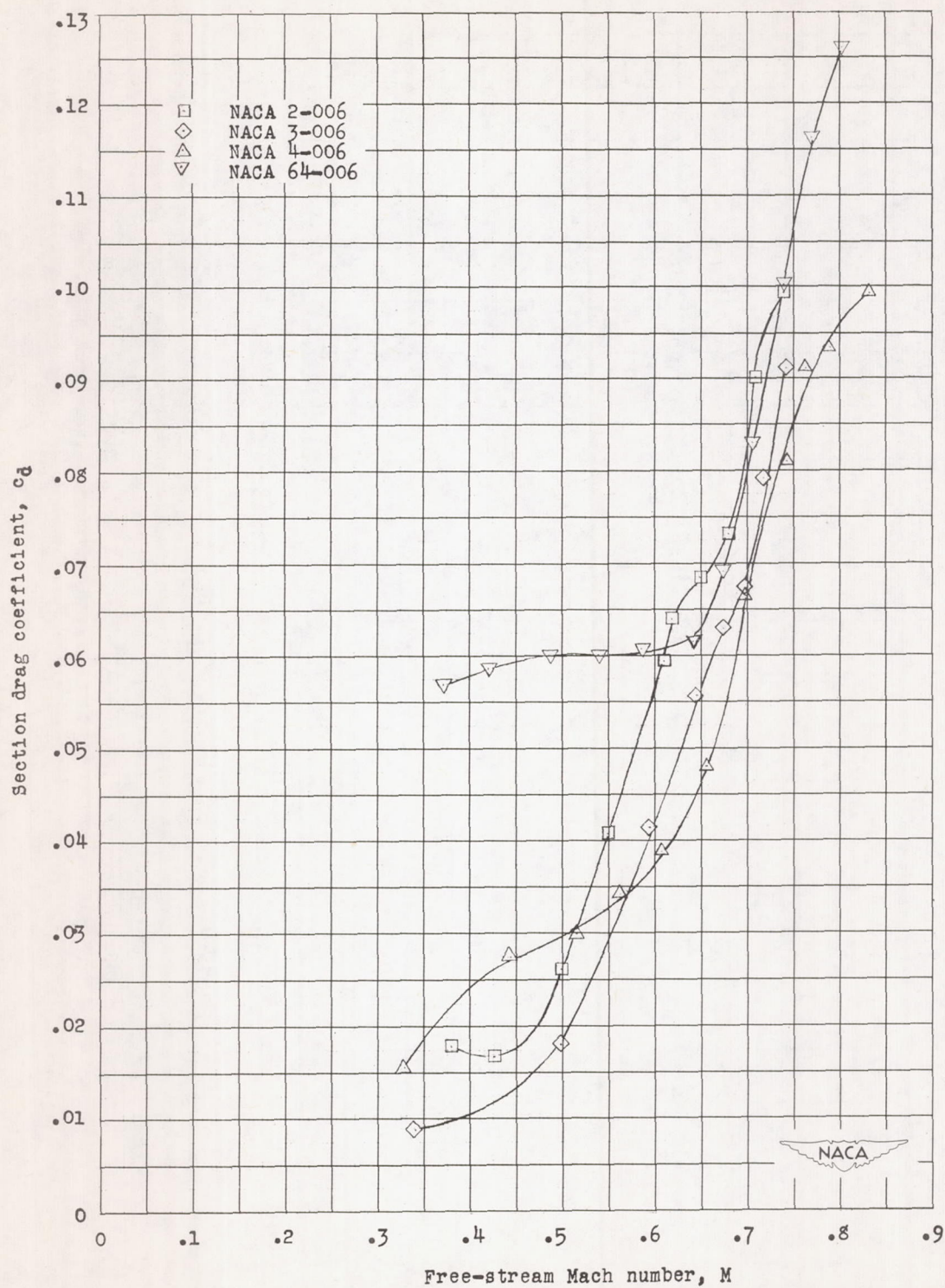
(a) $\alpha_0 = 0^\circ$.

Figure 11.- Variation of section drag coefficient with free-stream Mach number for several 6-percent-thick airfoil sections at three angles of attack.



(b) $\alpha_0 = 4^\circ$.

Figure 11.- Continued.



(c) $\alpha_0 = 6^\circ$.

Figure 11.- Concluded.

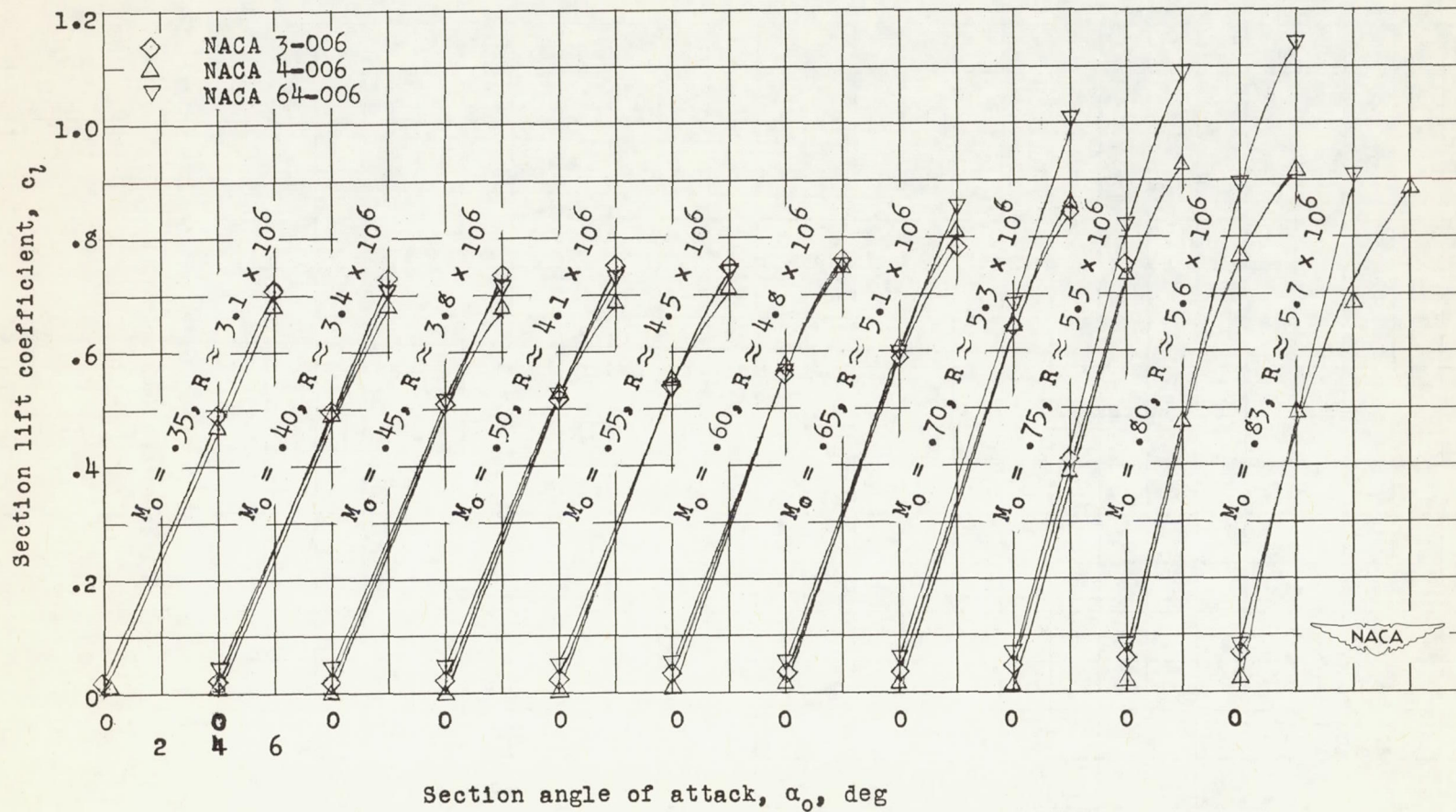


Figure 12.- Variation of the section lift coefficient with angle of attack for the NACA 3-006 and NACA 4-006 airfoil sections as compared with the NACA 64-006 airfoil section at various Mach numbers.

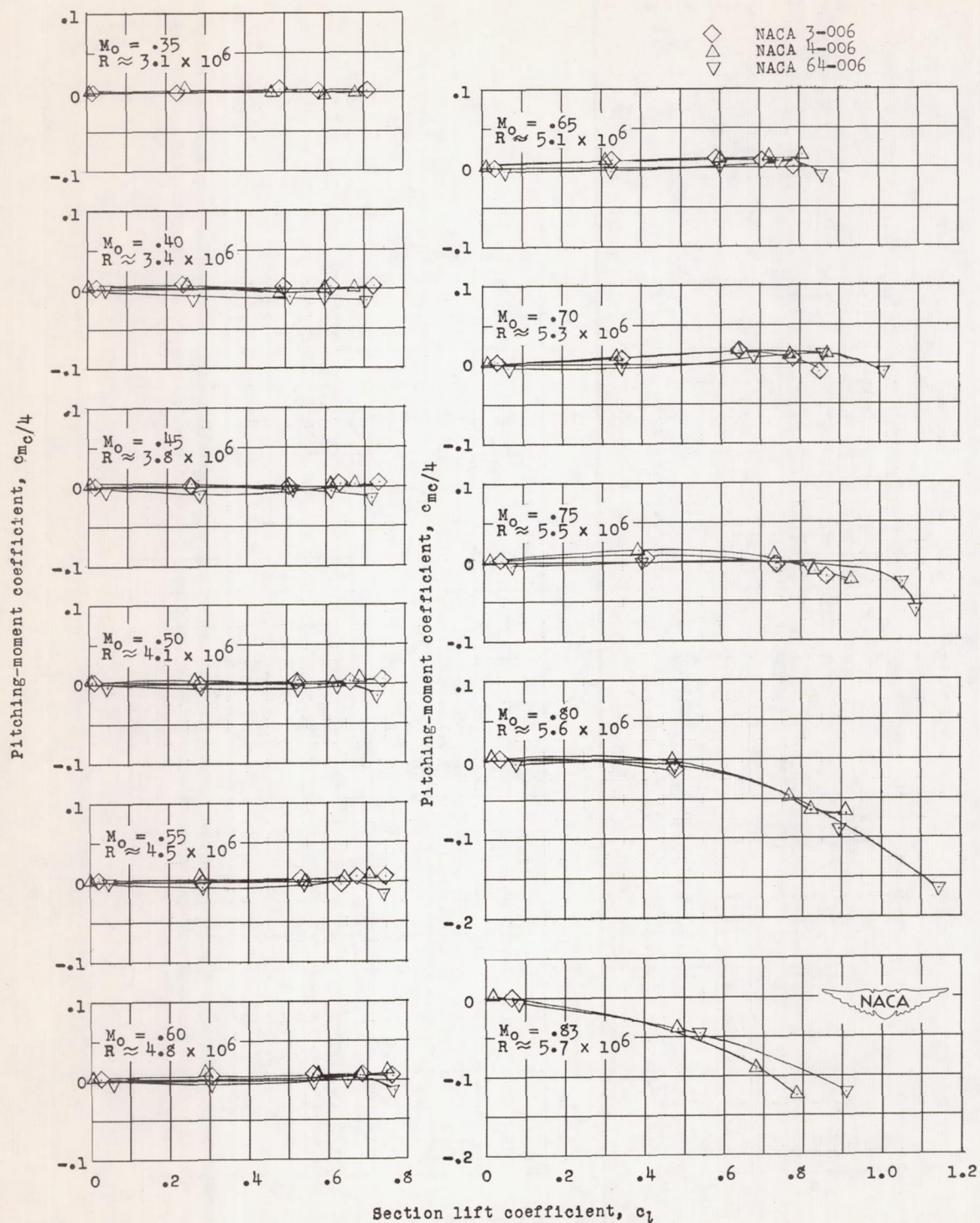


Figure 13.- Variation of section pitching-moment coefficient about the quarter-chord position with section lift coefficient for the NACA 3-006 and NACA 4-006 airfoil sections as compared with the NACA 64-006 airfoil section at various Mach numbers.

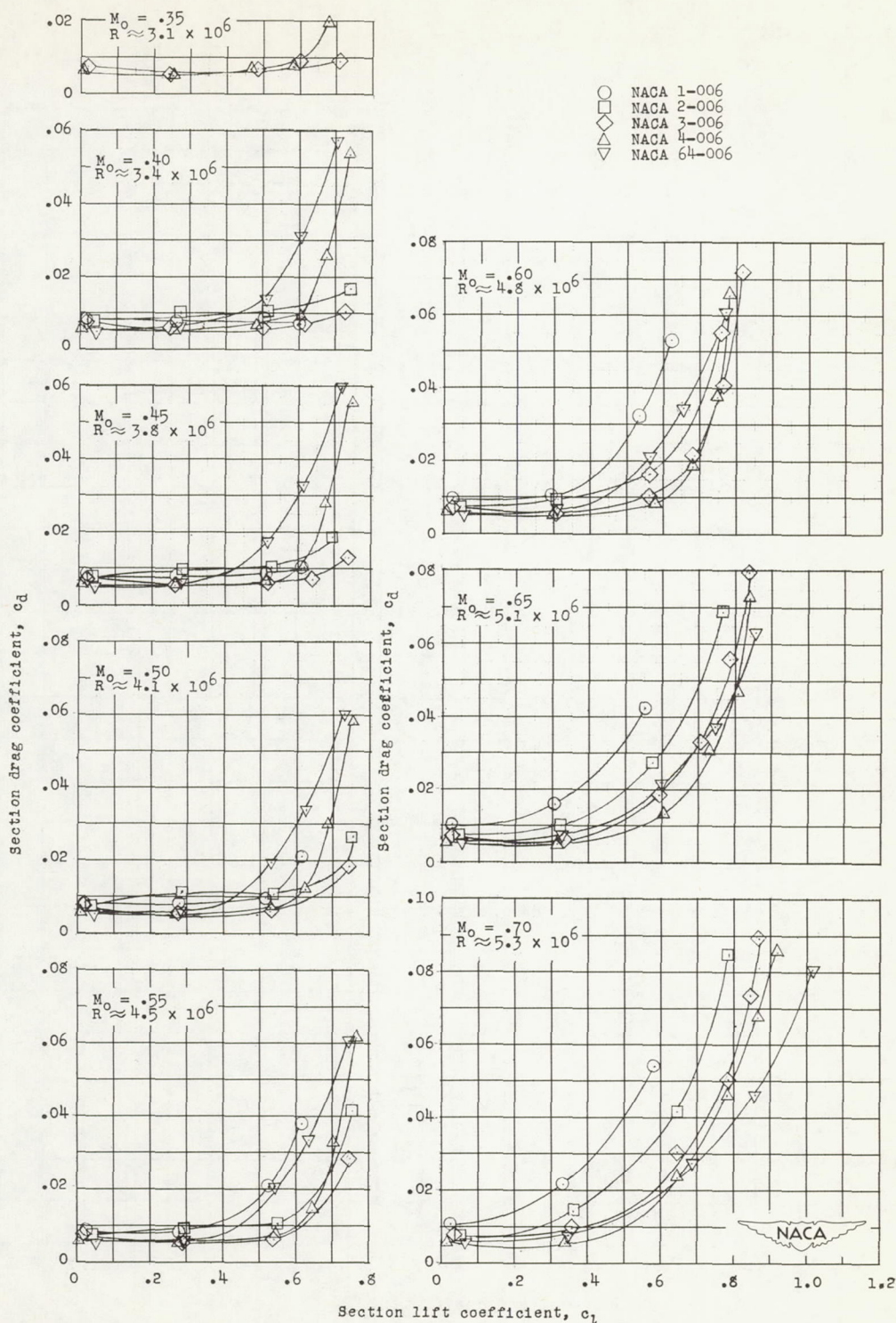


Figure 14.- Variation of section drag coefficient with section lift coefficient for five 6-percent-thick symmetrical NACA airfoil sections at various Mach numbers.

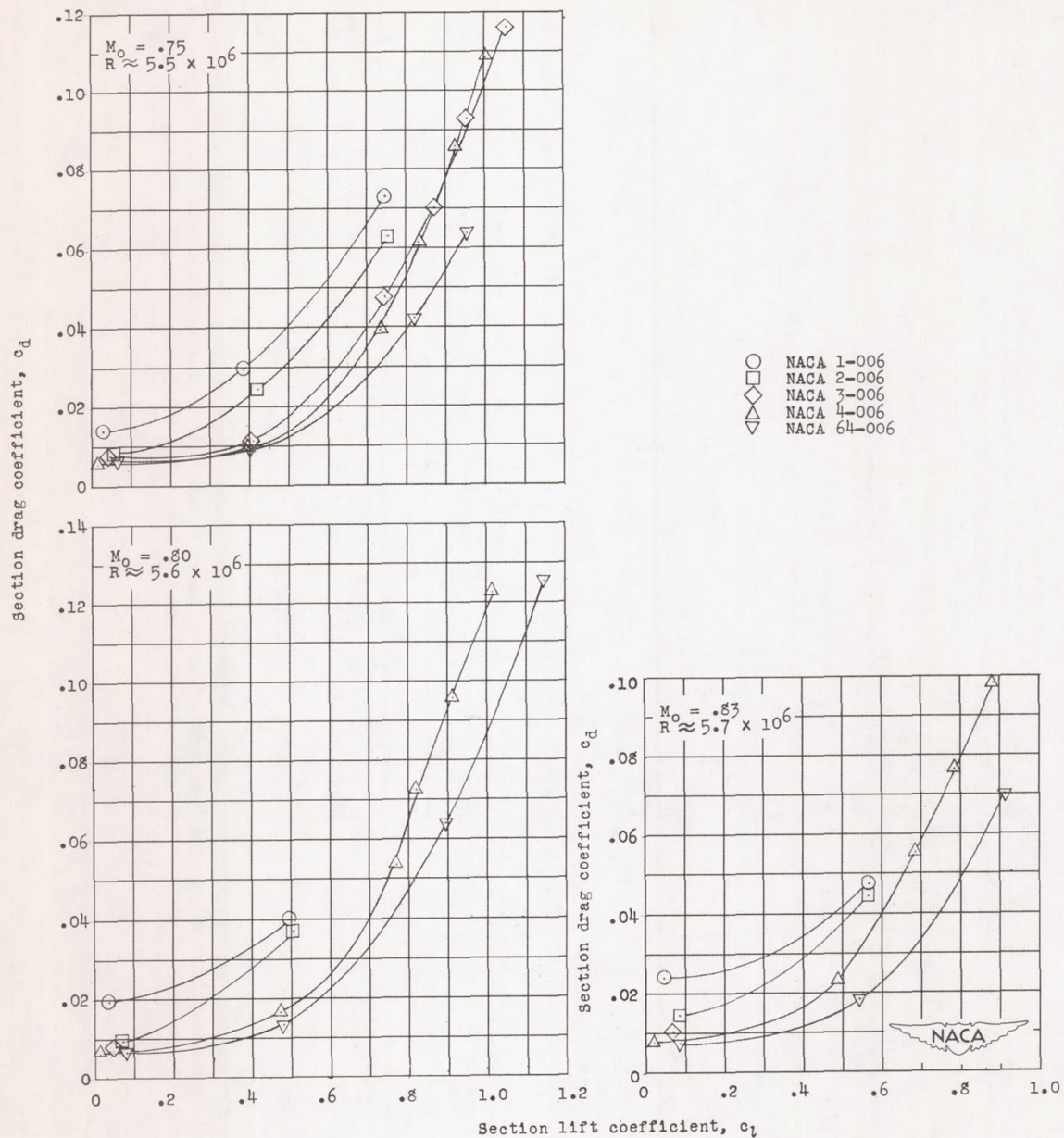


Figure 14.- Concluded.

